Perspective Plot

An Interactive Analytical Technique for the Visual Modelling of Land Management Activities

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PERSPECTIVE PLOT

An Interactive Analytical Technique for the
Visual Modelling of Land Management Activities

by

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PREFACE

It is the purpose of this book to document and illustrate a versatile package of computer routines for the visual modelling of land management activities. In developing PERSPECTIVE PLOT, the author has built on a base of work laid down by many talented individuals. Particular acknowledgement and appreciation is extended to: Roger Twito, U.S. Forest Service, Seattle, and John Warner, U.S. Forest Service, Portland, for their work on the prototype Perspective Plot technique; Daniel Lemkow, MacMillan-Bloedel Co., Ltd. Nanaimo, British Columbia, for his extensive work with digital terrain models; Michael Travis, U.S. Forest Service, Berkeley, for terrain attribute analysis procedures; Eric Mykelstad and J. Alan Wagar, Syracuse, New York, for their work on depiction of forest type textures; and Kent Simcoe, Stan Bemel, and Eldon Brown, Hewlett-Packard Company, for their technical assistance and encouragement during development of the PERSPECTIVE PLOT software.

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PERSPECTIVE PLOT

A. FUNCTION AND STRUCTURE

Advance design of many land management activities is done in plan view, using topographic maps or site plans. At some stage in the design process, the resource manager may be interested in the actual appearance of the planned activity. The ability to model the proposed activity as a viewer might see it would be a valuable addition to the planning process.

One technique available to the manager is the artist's rendering, drawn from on-site sketches or from photography. Objectivity may be at risk, however, since artwork may cast the artist's biases in a favorable light. Moreover, working strictly from topographic mapping to depict oblique perspectives is usually beyond human intuitive capabilities.

The advent of small, inexpensive desktop computer systems has made impartial, interactive visual modelling an attainable goal. The current generation of desktop computer combines high-speed operations, large memory size, and user ease with a versatile graphics capability. This hardware has made possible the development of a program package to perform an array of visual modelling tasks. This program, PERSPECTIVE PLOT, is designed to be:

1. interactive--the resource manager makes decisions as the solution develops,
2. graphical--information upon which decisions are made is portrayed in picture form,

and 3. friendly--the resource manager need not be a computer specialist to operate the program.

PERSPECTIVE PLOT was developed by the U.S. Forest Service Logging Systems Group in Portland, Oregon. Its initial purpose was the modelling of timber harvest proposals, so that the design skills employed in harvest planning would result in a degree of visual modification maintaining acceptable levels of scenic quality. Since the problems of both clearcut and partialcut harvest activities must be addressed, both types of harvest prescriptions can be modelled. The resource manager can work from the same topographic map or orthophotographic base used in other planning endeavors, and produce low-oblique perspective visual models of the planned activity.

PERSPECTIVE PLOT need not be limited to timber harvest activities. The program can be used to model utility corridors, ski areas, dams, roads, and structures. With a good understanding of the program and a fertile imagination, the resource manager may discover many more applications.

The program proceeds by first allowing the description of an activity feature. For example, a clearcut harvest boundary may be described as a set of points with certain planar and elevation coordinates, together with the height and shape of trees at each point. The tool used to formulate this feature description is the digitizer, which senses coordinate locations from the topographic map mounted on its surface.

Once an activity feature is described, the resource manager identifies a point from which to view the feature. Figure A1 shows the plan view of a clearcut harvest activity, with the

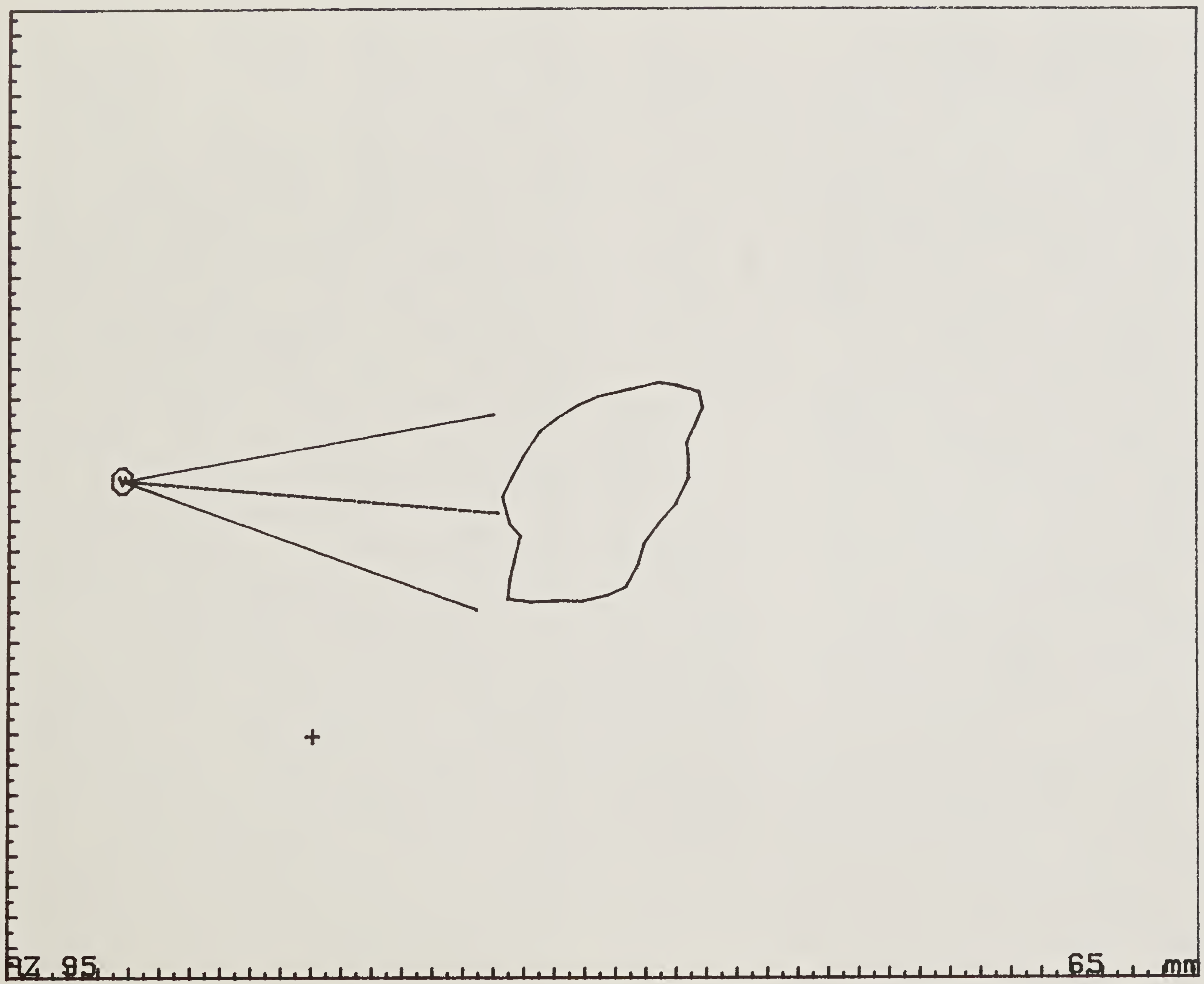


Figure A1. Plan view of a timber harvest activity proposal, with view centerline and field width lines radiating from viewpoint.

symbol (V) denoting the viewpoint. Notice that a line-of-sight (dashed line) and width-of-field (solid lines) radiate from the viewpoint toward the feature; horizontal orientation, vertical orientation, and width-of-field may be controlled from the computer keyboard. Moreover, the resource manager would do well to imagine that he is aiming a camera, set on a tripod located upon the viewpoint. He may point the camera in any direction and, by means of interchangeable lenses, obtain any desired width-of-field. The camera analogy is referred to repeatedly in this documentation, and is furthered by such means as the "focal length" readout, seen in the lower right corner of figure A1.

The PERSPECTIVE PLOT "camera" produces an image of the management feature in true perspective. Figure A2 is an example PERSPECTIVE PLOT image: the clearcut boundary shown in plan view in figure A1. Along the lower margin is a horizontal arc scaled in degrees azimuth. The left side is ruled with a vertical arc in degrees. The feature name appears in the upper left corner. The VIEW DISTANCE shown in the upper right corner will put the image in correct scale. Below this appears the viewpoint identification. The 35mm CAMERA LENS focal length shown in the lower right corner is a measure of the width-of-field: longer focal length lenses result in narrower field widths. If the user is familiar with 35mm format photography, he can easily relate focal length to width-of-field (see figure B8-2). Figures A3 and A4 explain how the PERSPECTIVE PLOT image differs from a photographic image, aside from providing a schematic picture of a feature not yet in existence. The PERSPECTIVE PLOT image is always held flat and vertical, at the indicated distance from the viewer's eyes, with level line-of-sight fixed on the zero-vertical-angle fiducial marks (or below or above frame if indicated).

PERSPECTIVE PLOT simulations can accurately model the following attributes:

* Form of forest openings or other shapes as perceived in oblique views
* Scale of management activity features, relative to surrounding features and landforms
* Comparative differences between various alternative proposals
* Textural modification in partial-removal timber harvest activities
* Visual statement of features associated with timber harvest activities (skyline corridors, road right-of-way, landings)
* Simple structural shapes (buildings, utility poles, earthwork, storage tanks)
* Screening of planned activities by intervening topography, vegetation, or structures.

PERSPECTIVE PLOT cannot be expected to model such attributes as:

* Color differences due to soil disturbance, seasonal conditions, or species selection.
* Fine textural detail (crown damage in residual timber, slash, complex structural shapes)

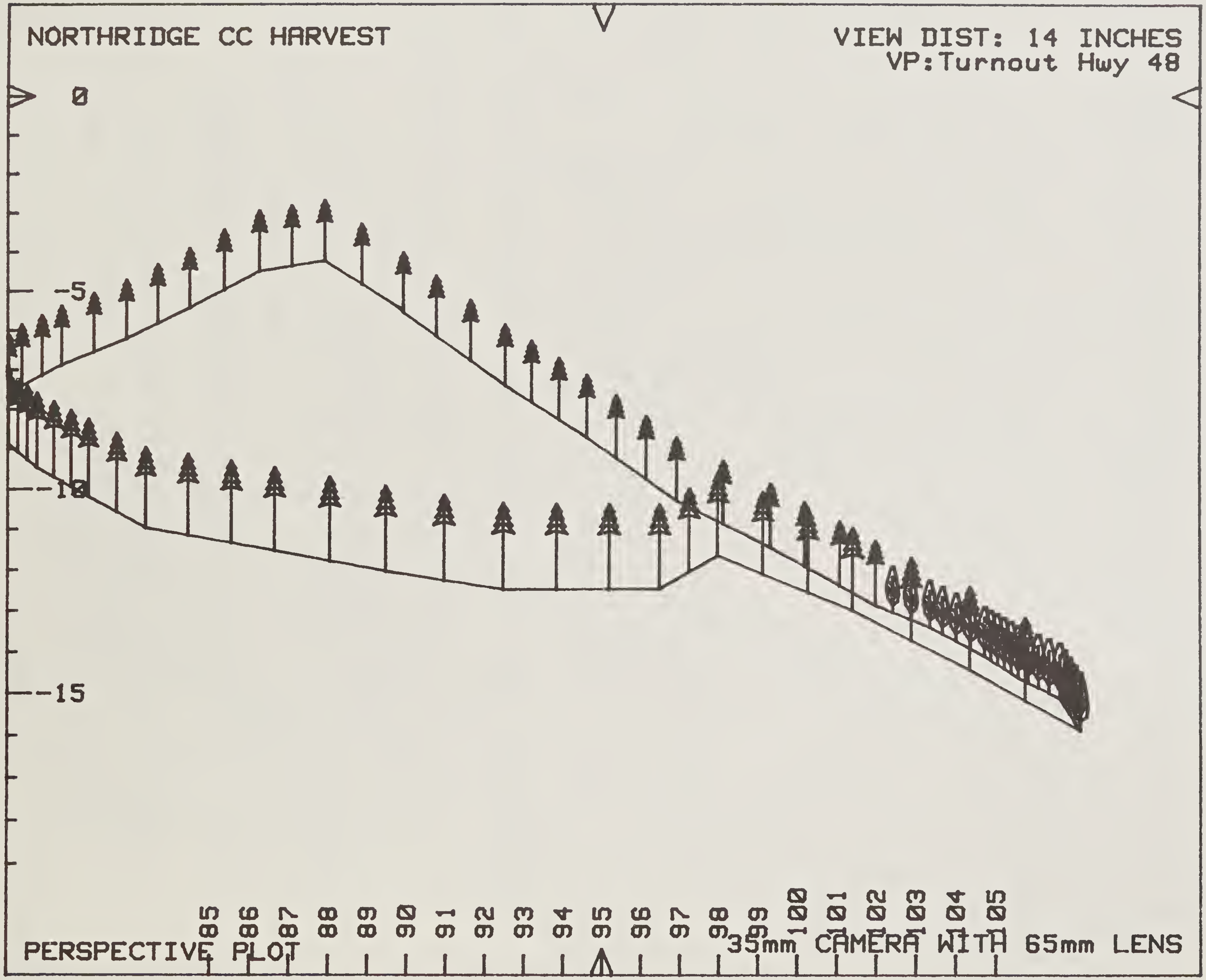


Figure A2. Timber harvest proposal shown in figure A1, perspective view.

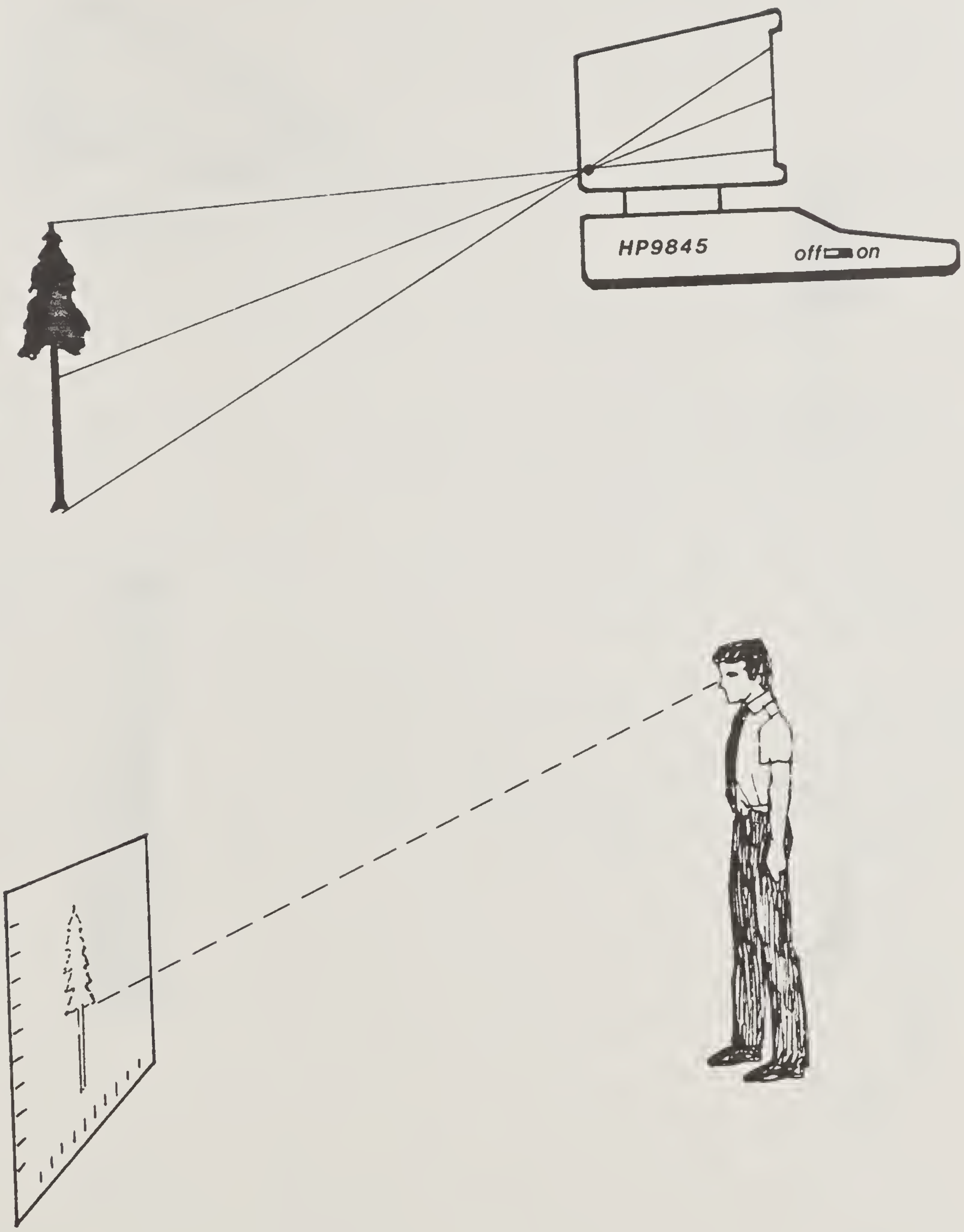


Figure A3. Orienting a PERSPECTIVE PLOT graphic. The graphic is held vertical, regardless of the line-of-sight vertical angle. This is easier to remember, and reflects the vertical orientation of the CRT surface. Spherical aberration is removed from the geometric analysis, so the graphic can be kept flat. Wide-angle views will not show distortion at the corners. Features will be in proper perspective when the graphic is viewed from the indicated distance. Level line-of-sight position is shown by fiducial marks or by a notation along the frame.

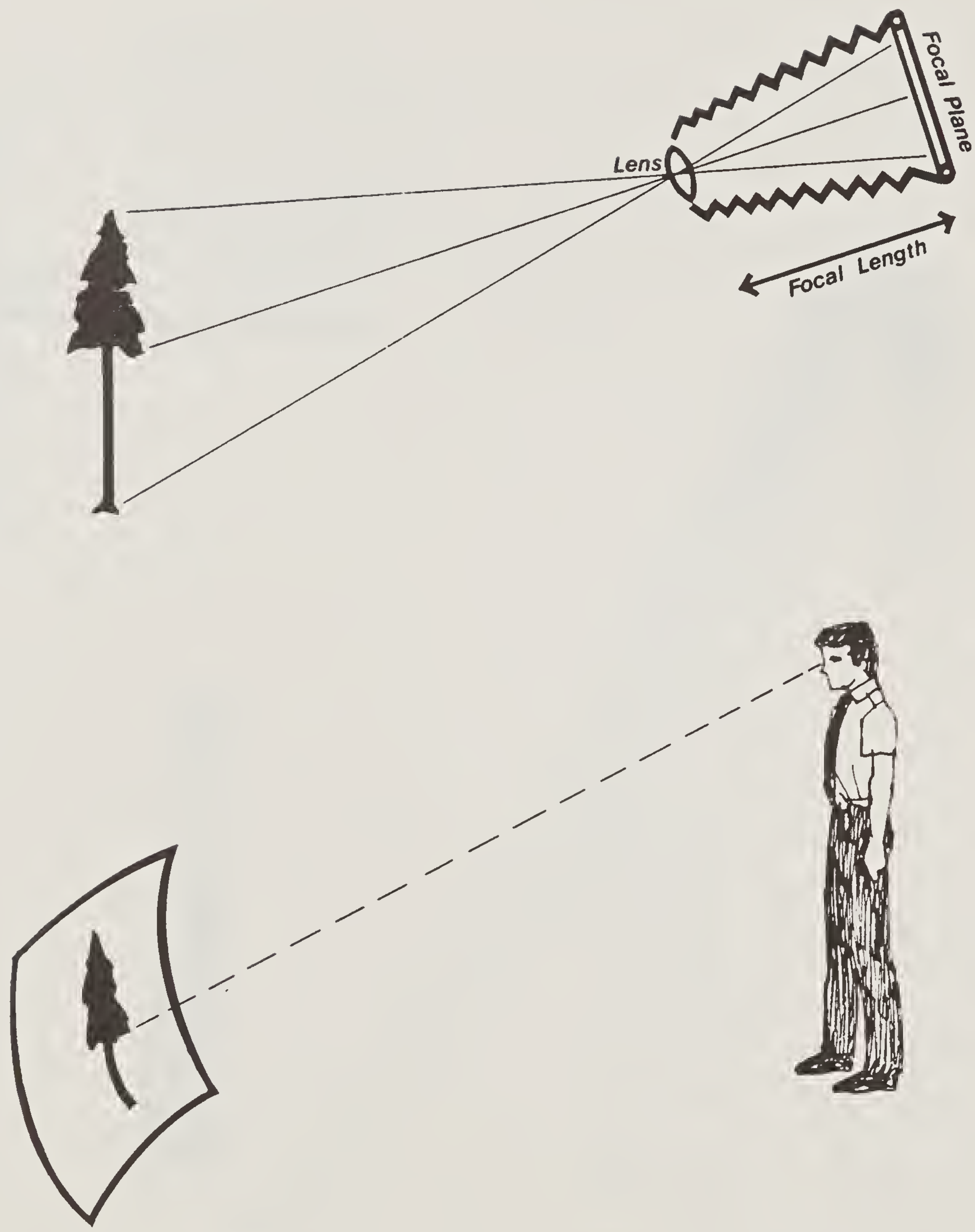


Figure A4. Orienting a photographic image. A photo must be tilted at the complement of the camera's line-of-sight vertical angle for proper viewing, due to the inclination of the film plane within the camera. Also, the photograph must be bent into a spherical surface with a radius equal to the camera's focal length (for contact prints) or greater (for enlargements) to assume the proper geometry, due to the lens system's spherical aberration. This effect is particularly noticeable in the "vignetting" apparent toward the corners of very short-focal-length ("fish-eye") photographs.

The PERSPECTIVE PLOT output can be used in several different ways, among which are:

* As information to the resource manager on the impact of his project proposals, i.e. as a DESIGN TOOL.
* As a base for artistic enhancement to produce a more realistic artist's conception over a geometrically "honest" framework (see figure C2-2), i.e. as an INTERMEDIATE PRODUCT.
* As a visual aid to illustrate resource activity alternatives to management and to concerned parties, i.e. as a PRESENTATION GRAPHIC.

The promise of PERSPECTIVE PLOT lies in these potential uses -- production of "the picture worth ten thousand words."

The PERSPECTIVE PLOT program is composed of a large number of segments, each allowing a different task or function. While no single segment is very complicated, the whole series fits together to give tremendous flexibility in choosing how to describe features and how to look at features. Each segment will be examined separately in sections B1 through B21, giving complete operating instructions. Section C contains case studies. The series of segments will be identified that resulted in the case study outputs.

Several of the case studies presented are fictitious in nature. That is, the projects modelled were never actually under consideration, although having great similarity to real-world projects from diverse geographic areas. The intent is to demonstrate the full range and potential of the PERSPECTIVE PLOT technique.

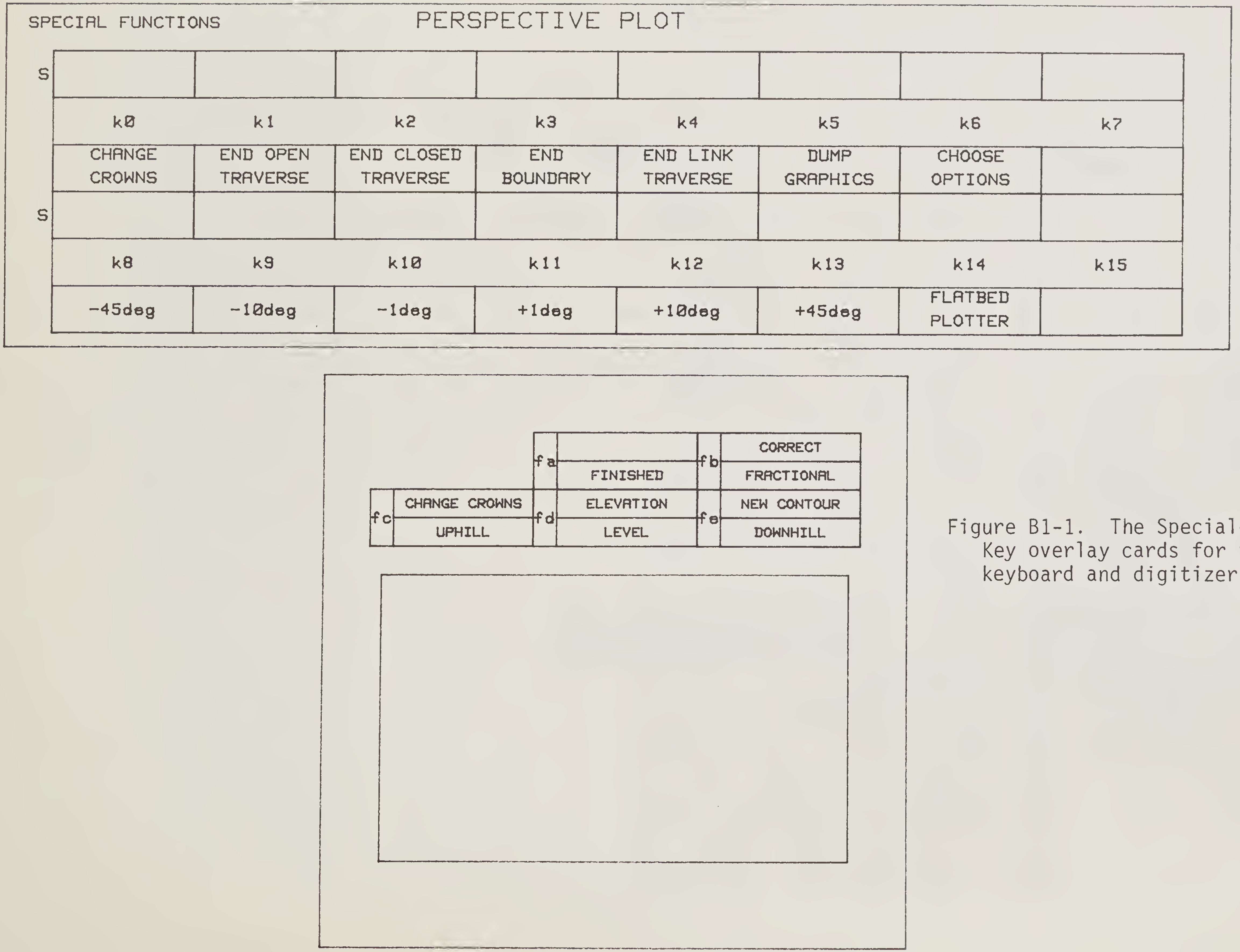


Figure B1-1. The Special-Function Key overlay cards for the main keyboard and digitizer keypad.

B. OPERATION

1. Startup

The PERSPECTIVE PLOT program was developed for the following computer hardware configuration:

HEWLETT-PACKARD 9845 S or T Desktop Computer
HEWLETT-PACKARD 9885M Flexible Disk Drive
HEWLETT-PACKARD 9872A Four-pen Flatbed Plotter
HEWLETT-PACKARD 9874A Digitizer

Departures from this configuration will require software modification, and perhaps revision of these operating instructions.

The PERSPECTIVE PLOT program resides on one flexible disk (the PROGRAM disk). A second disk stores data for Digital Terrain Models -- six models per disk (the DTM DATA disk). A third disk stores data for partialcut timber harvest projects -- one project per disk (the PARTIALCUT DATA disk). The program SETUP -- residing on the PROGRAM disk -- may be loaded and executed separately, to allow the setting-up of blank storage files on either a DTM DATA disk or a PARTIALCUT DATA disk.

Turn on the computer, plotter, digitizer and disk drive. Install the PROGRAM disk. Type the following command:

```
LOAD"PRSPLT:F8"
```

Press the EXECUTE key. When the first program segment has loaded (this takes about five seconds), press the RUN key. This is the only sequence of "system" commands a user will have to remember for the entire program. All other operations are direct responses to questions asked by the computer, or choices made from a list of options.

The TV screen (hereafter referred to as the Cathode Ray Tube, or CRT) displays the PERSPECTIVE PLOT logo and author's credits while an introductory block of instructions is printed. Accompanying the instructions is a replica of the keyboard and digitizer Special-Function Key overlay cards (figure B1-1). These cards should be prepared for use with the PERSPECTIVE PLOT program, and installed over the keyboard Special-Function Key block and the digitizer Special-Function Key block. After a pause of a few seconds, the CRT displays four feature-input options:

MODE 1 -- INPUT BOUNDARY BY TRAVERSE
MODE 2 -- DIGITAL TERRAIN MODEL
MODE 3 -- RECALL FEATURE FROM STORAGE
MODE 4 -- DIGITIZE DISCRETE POINTS ON FEATURE

The user types in the mode number he wants, and presses CONT

1. Startup

1. Turn on all hardware.
2. Install PROGRAM disk.
3. Type LOAD"PRSPLT:F8" EXECUTE
4. When program loads, press RUN
5. Select feature-input mode CONT

NOTE: Sections B2, B3, and B4 describe methods of building discrete-point models. These are features defined as a set of coordinates for each point on the boundary. While the computer can easily perform the geometric transformations to produce the true perspective spatial arrangement of the discrete points, the computer has no knowledge of terrain that may surround or lie within the array of discrete points. Consequently, the imagery produced has an "X-ray" effect: the computer cannot sort out what part of the feature may be hidden by intervening terrain because it has no information concerning the intervening terrain.

The X-ray effect may be overcome by modelling an entire piece of terrain upon which a feature is to be located. In fact, several other useful tasks may be performed with such a Digital Terrain Model. The technique is initially a bit more time-consuming than the discrete-point techniques, but much more informative. Sections B5, B9, B10, B11, and B17-21 pertain to Digital Terrain Model applications.

2. Discrete-point Feature -- Digitizer

The feature boundary should be drawn on a topographic map, using ink (pencil graphite, being electromagnetically conductive, may confound the digitizer; if pencil must be used, use a sharp, hard lead). Choose a map scale that will allow the entire project to fit within the black etched frame on the digitizer surface; larger scales do not add significantly to the resolution of the model. If this is not possible, consult the digitizer manual about the "axis-extend" maneuver. This simple operation can be mastered in less than five minutes, and enables unlimited translocation or rotation of a document larger than the digitizer work surface.

Align the map by digitizing a point in the western portion of the project area, followed by a second point due east. This procedure will define the cardinal directions. Note that the map may be oriented any way on the digitizer -- north need not be toward the top. Press [CONT] when finished aligning the map.

The CRT then prompts:

DIGITIZE FIRST POINT ON FIRST FIGURE

Choose an identifiable point to begin describing the activity, and digitize the point by locating the cursor and pressing the [D] key.

An axis is drawn across the bottom and up the left side of the CRT. Tic-marks indicate intervals of 100 feet (or 500 feet for large scales), with a "major" tic every 1000 feet. This is a "scratch" working area, covering 4550x5600 feet. The computer will begin drawing at the center of the screen.

The CRT displays the question:

MAP SCALE (ft per inch)?

Type this figure in. Note that for a 4"=1 mile map the proper response is 1320 [CONT] , since this scale is 1320 feet per inch.

The CRT displays the question:

CONTOUR INTERVAL (ft)?

Type in this figure followed by [CONT]

The CRT asks:

ELEVATION OF INITIAL POINT?

Type in the elevation followed by [CONT]

The CRT warns that the next entries will be made using the number pad on the digitizer. A siren sounds on the digitizer to attract the user's attention. The digitizer LED displays prompts for the tree crown information, as described in section

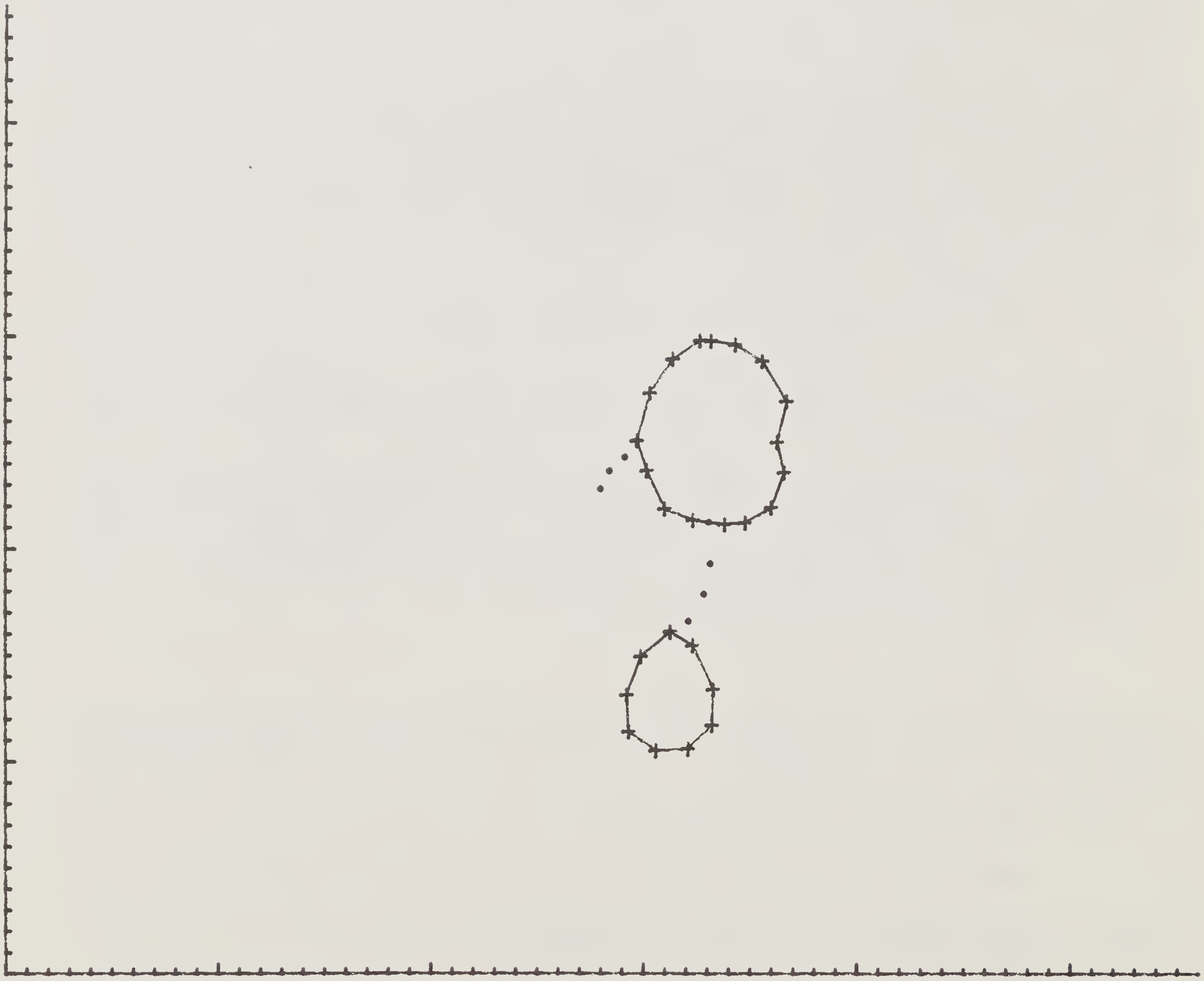


Figure B2-1. A "scratch" boundary graphic. A link traverse moved from the starting point northeast to the first unit, with another link south connecting to the second unit. Redone plot, upon pressing $\boxed{\text{CONT}}$, will show the two units at optimal scale, centered on the CRT.

B6. After describing the initial crown parameters, the CRT displays:

SELECT A SLOPE AND PROCEED

The user will move around the boundary digitizing the intersections of the boundary and contour lines, or noticeable turning points along the boundary. Permissible elevation changes are:

UPHILL by full contour intervals,
DOWNHILL by full contour intervals,
LEVEL,
or a FRACTION or multiple of a contour interval.

A digitizer function key corresponds to each option, and movement may be changed at any time.

In the case of FRACTIONAL movement, the digitizer display asks [FrACtION?] Respond by keying in the fraction or multiple of a contour interval desired, using the digitizer number pad. Note that [.] [5] [CHG SGN] [ENTER] results in movement downhill by one-half contour interval, while [3] [ENTER] results in movement uphill by three contour intervals.

The [ ] [fe] function key allows the direct input of a digitized point's elevation, prior to digitizing. This is useful in the case of features above or below grade, as depicted on the topographic map. See Case Study 2 and Case Study 7 for examples. The point's elevation is entered using the digitizer numeric keypad.

As digitizing progresses around the feature boundary, the annunciator tone raises or lowers in pitch, corresponding to movement uphill or downhill. The elevation of the last point digitized is shown on the digitizer display. Traverse information is printed, along with tree crown information. Key [ ] [fc] CHANGE CROWNS can be pressed at any time, to change the tree crown information (see section B6).

Upon reaching the end of a feature boundary, the [fa] FINISHED key is pressed. If the ending point is within 50 scale feet of the beginning point, the computer assumes that it was a closed boundary, and calculates the closing leg plus acreage enclosed. If more than 50 scale feet separates the endpoints, the CRT displays the question:

WAS FIGURE NO. 1 AN OPEN (O) OR CLOSED (C) FIGURE?

Type in O or C [CONT] and the computer takes appropriate action.

The CRT then asks:

WANT TO DIGITIZE ANOTHER FIGURE(Y or N)?

Answer as appropriate, with Y or N [CONT] The procedure starts over if another figure is to be digitized. If the response was N, then the CRT displays the "scratch" plot of the features -- plan view -- as digitized. Note that the boundary

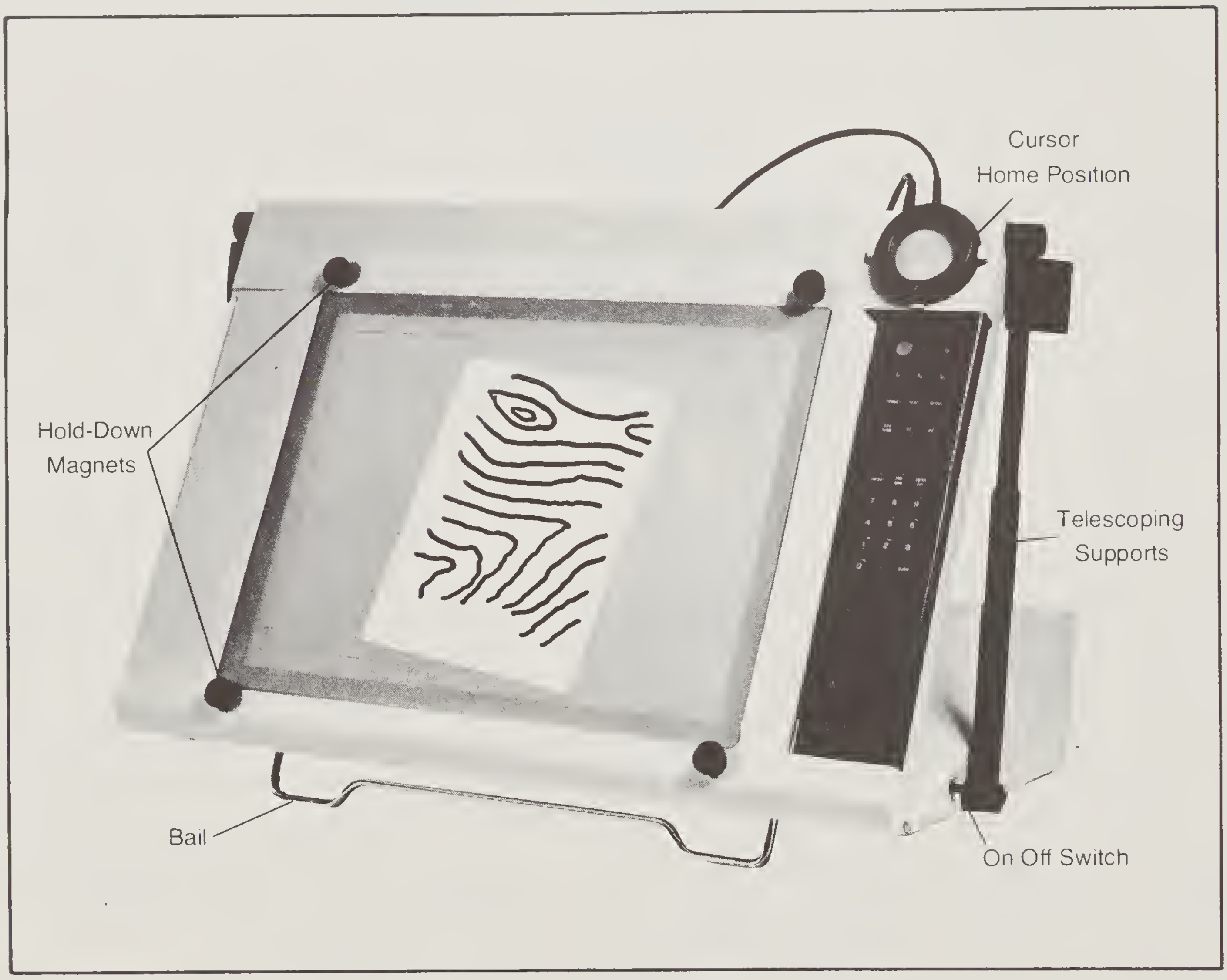


Figure B2-2. The HP9874A Digitizer.

may have wandered outside the CRT field of view. Upon pressing $\boxed{\text{CONT}}$ the boundary is replotted at a scale that takes up the entire CRT, nicely centered, with an axis along the bottom and left, ticked every 100 or 500 feet, major tics every 1000 feet. Press Special-Function Key $\boxed{\text{k5}}$ DUMP GRAPHICS on the computer keyboard to make a hard copy of the graphic. Then press $\boxed{\text{CONT}}$.

The CRT displays the question:

WANT TO STORE BOUNDARY INFORMATION(Y or N)?

Responding Y $\boxed{\text{CONT}}$ branches to the segment described in section B16 -- Storage of Feature Data.

Next, the program branches to the viewpoint location segment, described in section B7.

2. Discrete-point Feature -- Digitizer

1. Align document on digitizer.
2. Input MAP SCALE (ft/inch) $\boxed{\text{CONT}}$
3. Input CONTOUR INTERVAL (feet) $\boxed{\text{CONT}}$
4. DIgitize initial point, first figure
5. Input ELEVATION OF FIRST POINT $\boxed{\text{CONT}}$
6. Input tree crown information from digitizer keypad. This may be changed any time, using $\boxed{}$ $\boxed{\text{fc}}$ (see section B6)
7. SELECT A SLOPE AND PROCEED to digitize around the feature boundary
8. Press fa when finished. Indicate whether an open or closed figure, as required
9. DIGITIZE ANOTHER FIGURE? If yes, go back to step 4
10. When finished, press $\boxed{\text{CONT}}$ for replot. DUMP GRAPHICS $\boxed{\text{k5}}$ if desired, then press $\boxed{\text{CONT}}$
11. STORE BOUNDARY INFORMATION (section B16) if desired
12. Program branches to Viewpoint Location (section B7)

LINK TRAVERSE TO FIGURE 1

SLOPE DIST	% SLOPE	AZIMUTH	ELEVATION
			1250
100	-32	26	
			1220
100	-28	49	
			1193
100	-28	36	
			1166

TRAVERSE OF FIGURE 1 BEGINS HERE

FIGURE NUMBER 1

POINT #	SLOPE DIST	PCNT SLOPE	AZI-MUTH	ELEV	TREE HT	CROWN PCT	CROWN WIDTH	COMMENT
1				1166	150	35	40	START
	250	-42	15					
2				1069	150	35	40	DOWNHILL
	200	-29	34					
3				1013	150	35	40	DOWNHILL
	158	-18	56					
4				985	150	35	40	DOWNHILL
	55	-45	93					
5				963	150	35	40	DOWNHILL
	120	27	99					
6				994	150	35	40	UPHILL
	150	15	122					
7				1016	150	35	40	UPHILL
	225	21	149					
8				1062	150	35	40	UPHILL
	200	20	193					
9				1102	150	35	40	UPHILL
	150	25	167					
10				1138	150	35	40	UPHILL
	180	22	200					
11				1177	150	35	40	UPHILL
	150	35	240					
12				1226	150	35	40	UPHILL
	100	30	266					
13				1255	150	35	40	UPHILL
	150	5	278					
14				1262	150	35	40	UPHILL
	150	-32	292					
15				1217	150	35	40	DOWNHILL
	200	-16	335					
16				1185	150	35	40	DOWNHILL
	150	-13	342					
17				1166	150	35	40	DOWNHILL--CLOSED

AREA OF UNIT = 10.7 ACRES

LINK TRAVERSE FROM FIGURE 1 TO FIGURE 2 STARTING AT POINT 12.5

SLOPE DIST	% SLOPE	AZIMUTH	ELEVATION
			1259
200	25	178	
			1307
150	20	192	
			1337
150	22	210	
			1369
100	27	240	
			1395

TRAVERSE OF FIGURE 2 BEGINS HERE

FIGURE NUMBER 2

POINT #	SLOPE DIST	PCNT SLOPE	AZI-MUTH	ELEV	TREE HT	CROWN PCT	CROWN WIDTH	COMMENT
18				1395	150	35	40	START
	185	24	230					
19				1438	150	35	40	UPHILL
	200	28	200					
20				1492	150	35	40	UPHILL
	185	40	177					
21				1561	150	35	40	UPHILL
	165	34	125					
22				1614	150	35	40	UPHILL
	150	4	87					
23				1620	150	35	40	UPHILL
	167	-32	45					
24				1569	150	35	40	DOWNHILL
	175	-33	2					
25				1514	150	35	40	DOWNHILL
	235	-26	335					
26				1455	150	35	40	DOWNHILL
	137	-49	302					
27				1395	150	35	40	DOWNHILL--CLOSED

AREA OF UNIT = 3.9 ACRES

Figure B3-1. Traverse Boundary notes, as printed upon input. This boundary is plotted in plan-view in figure B2-1.

3. Discrete-point Feature -- Traverse Data

Activity features may be described by field traverse notes. This option is particularly useful after an activity has been designed on paper and laid out in the field. PERSPECTIVE PLOT displays will verify whether the designed effect has been successfully transferred to the ground.

Select Mode 1 -- boundary input by traverse. The CRT asks:

ELEVATION OF INITIAL POINT?

Enter this figure. The CRT asks a series of questions that describe the initial tree crown size and shape. See section B6 for a full discussion. A heading for traverse notes is printed, as seen in figure B3-1. Next the CRT enters graphic display mode and lays off a 4550x5600 foot "scratch" working area (see figure B2-1). The initial point is in the center, marked by a small "+" symbol. Since the first point may be a benchmark, peak, saddle, road terminus, or other feature of known elevation not actually on the activity boundary, the CRT asks:

TRAVERSE TO STARTING POINT OF FIGURE NO. 1 (Y or N)?

If yes, successive traverse inputs will serve to move to the starting point of the first boundary figure. In response to the prompt:

SLOPE DISTANCE, % SLOPE, AZIMUTH

enter these three values for each leg of the traverse, separated by commas. Terminate the link traverse by pressing Special-Function Key $\boxed{k4}$ END LINK TRAVERSE. The next traverse inputs will define the boundary of figure 1. Enter the same type of traverse data in the same way. Press Special-Function Key $\boxed{k0}$ CHANGE CROWNS at any time to alter the crown size and shape. Press $\boxed{k1}$ END OPEN TRAVERSE or $\boxed{k2}$ END CLOSED TRAVERSE to terminate the figure. The CRT will ask:

TRAVERSE TO STARTING POINT OF FIGURE NO.2(Y or N)?

Answer as appropriate. If yes, the CRT asks:

START LINK TRAVERSE AT LAST POINT PLOTTED (Y or N)?

Answer as appropriate. If no, the user may select the initial point of the link traverse by point number, with the additional bonus of picking a non-integer point. For example, if the link traverse starts halfway between point 6 and point 7, the user answers 6.5 $\boxed{\text{CONT}}$ in response to the prompt:

POINT NUMBER FOR START OF LINK TRAVERSE (MAY BE NON-INTEGER)?

Continue to link boundary figures together. When done, press $\boxed{k3}$ FINISHED BOUNDARY. The CRT graphic display comes on, showing the "scratch" plan-view plot of the activity boundary. Press $\boxed{CONT}$ and the boundary will be replotted to large scale, centered on the CRT. Press $\boxed{CONT}$ again and the CRT asks:

BOUNDARY DATA DESCRIPTION (UP TO 60 CHARACTERS)? stops here--

Type this in and press $\boxed{CONT}$. The CRT then asks:

DO YOU WANT TO STORE THIS BOUNDARY DATA(Y or N)?

Answer as appropriate. Feature boundary data storage is discussed in section B16.

Following this, the program branches to the Viewpoint Location segment, described in section B7.

3. Discrete-point Feature -- Traverse Data

1. Input ELEVATION OF INITIAL POINT $\boxed{CONT}$
2. Link traverse to start of activity boundary if desired.
3. Input traverse around boundary.
4. Traverse inputs are SLOPE DISTANCE, % SLOPE, AZIMUTH
5. Use Special-Function Keys to end link traverses, open traverses, closed traverses, or entire boundary input.
6. Successive links and figures -- go back to step 2.
7. Press $\boxed{CONT}$ for replot. DUMP GRAPHICS if desired. Then press $\boxed{CONT}$ again.
8. STORE BOUNDARY INFORMATION (section B16) if desired.
9. Program branches to Viewpoint Location (section B7).

4. Discrete-point Feature -- Retrieval from Storage

Six locations for storing activity feature information are provided on the PROGRAM disk. Feature boundaries produced by digitizing, traverse, or from a Digital Terrain Model may be stored in one of the six locations. The user may then retrieve the feature information for further examination at a later date.

Upon selecting the option for feature retrieval from storage, the user is presented with a list containing the names of the six activities stored. The CRT displays:

RETRIEVE BOUNDARY FROM WHICH FILE (1-6)?

Type in the desired number, followed by $\boxed{\text{CONT}}$ The file is retrieved from the disk, the CRT clears, and a plan view of the activity is plotted. Upon pressing $\boxed{\text{CONT}}$ the program branches to the output options segment.

4. Discrete-point Feature -- Retrieval from Storage

1. CRT displays six activity names.
2. Choose desired number $\boxed{\text{CONT}}$
3. CRT produces plan-view plot.
4. Press $\boxed{\text{CONT}}$ Program branches to output options.

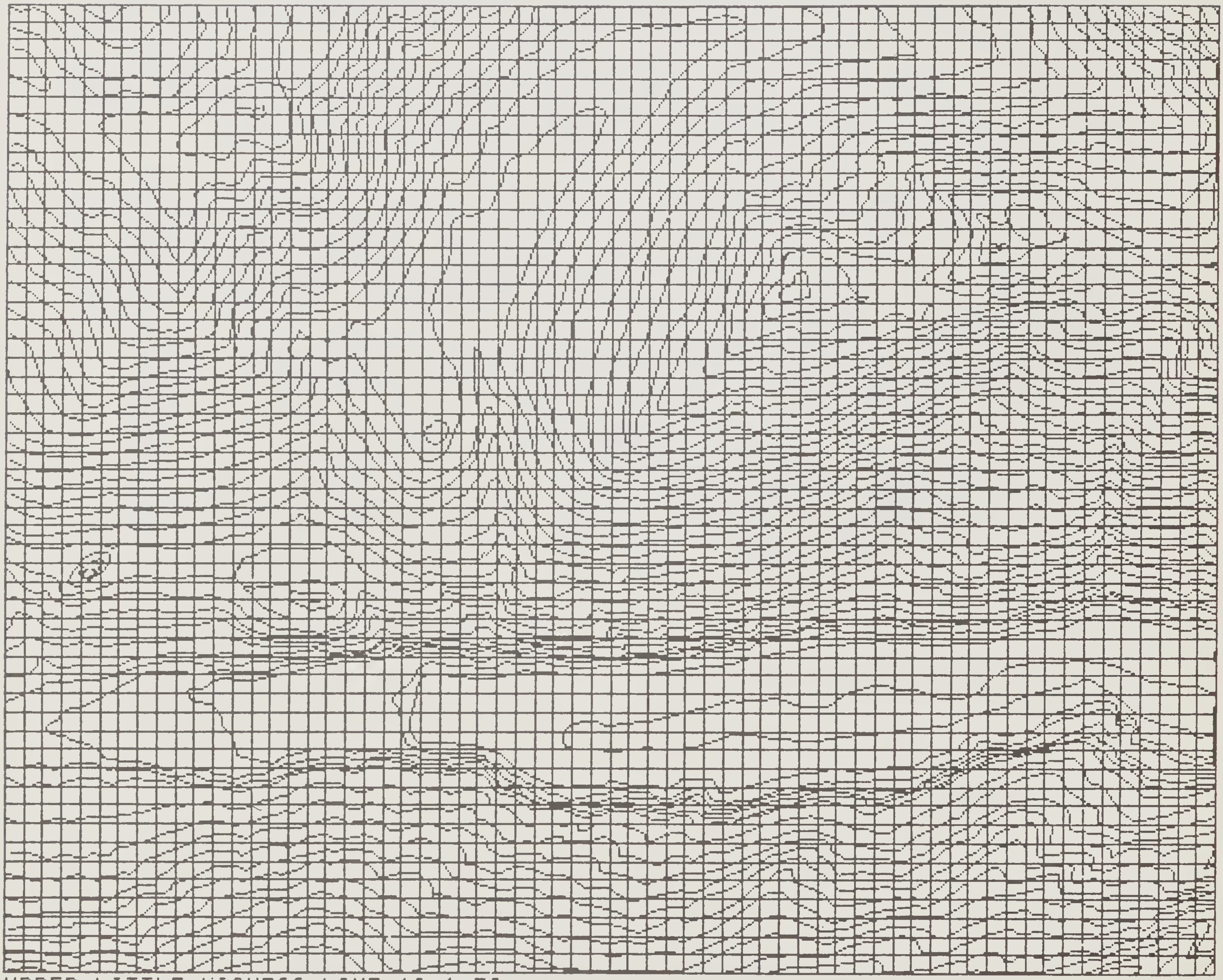


Figure 5-1. A Digital Terrain Model (DTM) covering about 4400 acres. The contours as digitized are shown, overlain by the grid of elevation points that constutes the computer's numerical model of the terrain.

5. Feature from Digital Terrain Model

What is a Digital Terrain Model

Sections B2, B3 and B4 deal with management activity features portrayed as discrete-point models. That is, the feature is described to the computer as a series of discrete points (defined by rectangular coordinates: X,Y,elevation) along the boundary of the activity, together with information as to the size and shape of the figure located at each point. Discrete-point features are computationally easy, make efficient use of computer storage space, and can be built with simple procedures. There is one grave drawback: hidden lines cannot be removed in perspective simulations. Since the computer has no information on terrain inside the boundaries of the feature or between the feature and the viewpoint, the computer cannot determine which parts of the activity feature are screened from view. Therefore, discrete-point feature models are shown as if the viewer had X-ray vision. Size and shape of features may consequently be grossly misrepresented.

The solution is to present the computer with descriptive information on the entire piece of terrain involved. Such information is called a Digital Terrain Model (DTM). A DTM is the numerical equivalent of a topographic map, aerial photograph, or relief model. The PERSPECTIVE PLOT Digital Terrain Model is a grid of elevations, evenly spaced in the X (east-west) and Y (north-south) directions, derived by digitizing the contours of a topographic map (see figure B5-1). The spacing of grid points is a function of the size of the area being portrayed in a single model. The maximum model is a grid of 65x53 points, or 3445 elevation points. If the area modelled were 100 acres, nearly 35 elevations per acre would be retained, comprising a grid of points approximately 36 feet apart. A 3500-acre model would consist of approximately one elevation per acre, or a grid spacing of about 210 feet. It can be seen that model resolution varies directly with the size of the area portrayed.

The shape of the area covered in a DTM is rectangular, and of the same length-to-width ratio as the CRT (hence the dimensions 65x53). The entire DTM need not be filled-in. The computer retains an elevation of -32768 for grid points missing or undefined in the DTM (computer buffs will recognize this number as the maximum negative 16-bit binary integer). Other grid points are defined by an integer elevation (feet). Any point on an activity feature must be located in a grid cell with all four corners defined (possessing an elevation other than -32768), or else the point is regarded as "outside of" the DTM and will not be portrayed in perspective simulations.

Each DTM stands alone, in keeping with the project-oriented nature of the PERSPECTIVE PLOT program. No provision has been made for splicing together adjacent DTMs, or adding to a DTM once it has been completed. Constructing a DTM, however, is neither difficult nor unduly time-consuming, once a user has become familiar with the procedure. Section B17 covers the DTM construction procedure at length.

A DTM affords the opportunity to:

* describe boundary-type features with extreme ease
* portray the terrain itself in perspective view
* handle partial-cut timber harvest prescriptions, as well as other vegetation and surface textures
* assess terrain attributes such as slope and aspect
* remove hidden lines -- turn off the "X-ray" effect
* determine the extent of area seen from a viewpoint
* describe and permanently store an entire block of terrain, so that it may be retrieved for future analysis
* obtain low-standard engineering information, such as profiles, road alignment, earthwork volume.

How is an Activity Feature protrayed from a DTM

Upon selecting the DTM approach to describing an activity feature, the user is presented with a brief description of the PERSPECTIVE PLOT DTM and the procedure for its construction. The computer asks:

Want to retrieve a DTM you have previously stored (Y or N)?

Answering Y [CONT] takes the user to the DTM retrieval procedure described in section B19. Answering N [CONT] takes the user to the DTM construction procedure described in section B17. When a DTM has been obtained by one procedure or the other, the program offers a choice of DTM outputs, described in section B20:

1. Depict clearcut timber harvests or boundary-type features
2. Depict partialcut timber harvests or area-type textural features.
3. Distorted-square terrain depiction
4. Analysis of terrain attributes, plus engineering information.

Output choice 1 will be discussed further in this section.

Clearcut timber harvests or boundary-type features to be protrayed should be drawn on the map, in ink or hard-lead, fine-point graphite (ink is better!). Either the original base map or the thermal-printer replica may be used. Affix the map to the digitizer surface. The computer will ask which base map is being used. Upon receiving an answer, the computer asks the user to digitize the southwest and southeast corners of the rectangle enclosing the DTM area, thereby aligning the map. If the thermal-printer replica is used, these points are simply the lower-left and lower-right corners of the box surrounding the DTM. If the original map base is used, these points SHOULD HAVE BEEN CLEARLY MARKED by the user, as instructed in section B17. Press [CONT] on completion of the map alignment procedure.

The computer warns that subsequent inputs will be from the digitizer. A siren sounds to attract the user's attention to the digitizer display, which asks for tree crown data, as described in section B6. Then the display prompts the user to [DGt2E FIG 1]

The boundary of the first figure may be digitized. The

digitizer automatically enters the continuous-sample mode upon starting a new figure, but this may be overridden by pressing the [SINGLE] key on the digitizer. The user has better control over the number and spacing of boundary points if he goes to single-sample mode. Move the cursor around the figure boundary. Elevations are being obtained from the DTM! A boundary is plotted on the CRT, and no line shows if the cursor is taken outside the limits of the DTM. Digitizing can be stopped at any time. The tree crown figure can be changed, by pressing [ ] [fc] CHANGE CROWNS. When finished with the figure, press [Fa] FINISHED. If the end point is within 50 feet of the beginning point, the figure is assumed to be a closed boundary; the closing link is computed and the acreage is printed. Otherwise, the user is asked:

IS FIGURE 1 A CLOSED (C) OR AN OPEN (O) FIGURE?

Respond appropriately. The computer then asks:

WANT TO DESCRIBE ANOTHER FIGURE(Y or N)?

Answer as appropriate.

When all figures within the feature have been described, an opportunity is given to store the feature (see section B16). Upon storage, the feature data is no longer associated with the DTM, hence the stored data becomes a discrete-point model when called back later from storage. The program branches to identification of a viewpoint location, described in section B7. Note that, for viewpoints within the DTM, the elevation is automatically obtained from the DTM. Otherwise, the user is asked to supply the required elevation. Viewer height above the ground is a required input, since the DTM records ground elevations. Because the DTM approach allows determination of hidden relief, it is important that the viewer's eye be above the terrain. Otherwise, very slight variations in relief may screen all features from the viewer.

After viewpoint selection, the activity feature is replotted in plan view to a scale that allows inclusion of the viewpoint. Then the computer CRT displays:

Determination of hidden lines will take approximately xx.x minutes. You may choose to skip determination of hidden lines.
WANT TO SKIP DETERMINATION OF HIDDEN LINES (Y or N)?

If the user should desire an "X-ray" perspective depiction of the feature, or should it be apparent from the topography that the entire feature is directly visible, the step can be skipped. Otherwise, the CRT again shows the plan-view graphic, with a flashing "+" crosshair moving rapidly from each boundary point back toward the viewpoint. As it moves, the computer is moving along a terrain profile, determining whether the intervening terrain hides the boundary point. If the point is not hidden, an asterisk is drawn over the point. When all points have been examined, a hard copy of the plan-view graphic is automatically produced (figure B5-2). The program branches to selection of

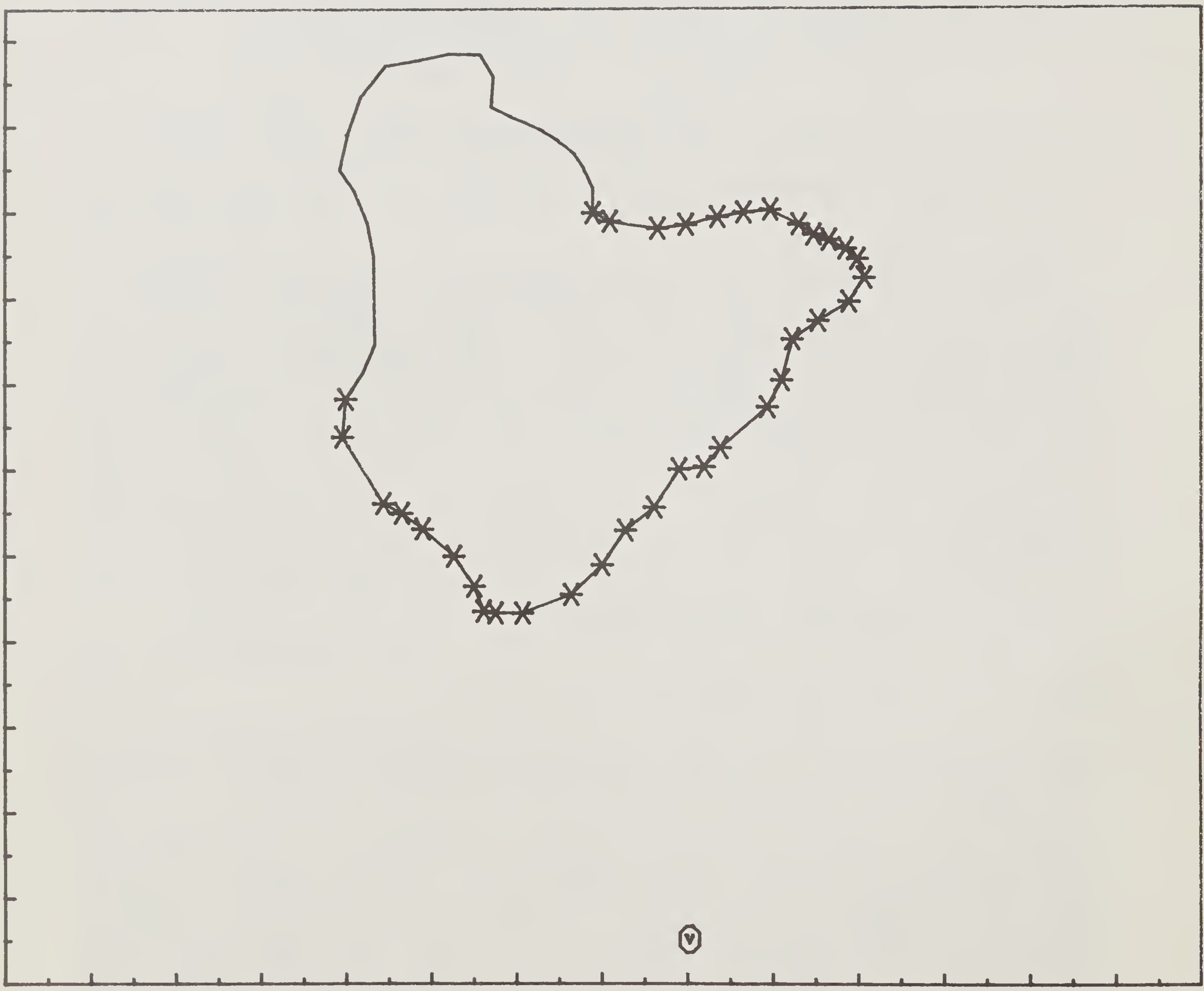


Figure B5-2. Once a feature boundary has been digitized from the DTM, the computer determines boundary points visible at the viewpoint and marks them with an asterisk.

view direction and width-of-field (section B8) and selection of a branching or output option (section B14).

5. Feature from Digital Terrain Model

1. Obtain a DTM by constructing it or retrieving it from storage.
2. Mount original map or thermal-printer replica on digitizer, with feature boundaries shown.
3. Align the map by digitizing the southwest and southeast corners.
4. Input tree crown information from digitizer key pad. This may be changed any time, using $\boxed{}$ $\boxed{fc}$ (section B6).
5. Digitize boundary of the first figure, using either single or continuous sampling.
6. Press $\boxed{fa}$ when finished. Indicate whether an open or closed figure, as required.
7. DIGITIZE ANOTHER FIGURE? If Yes, go back to step 5.
8. When finished, press $\boxed{CONT}$ and the feature is replotted. DUMP GRAPHICS $\boxed{k5}$ if desired, then press $\boxed{CONT}$
9. STORE BOUNDARY INFORMATION (section B16) if desired.
10. Program branches to viewpoint location (section B7), followed by hidden-line determination.

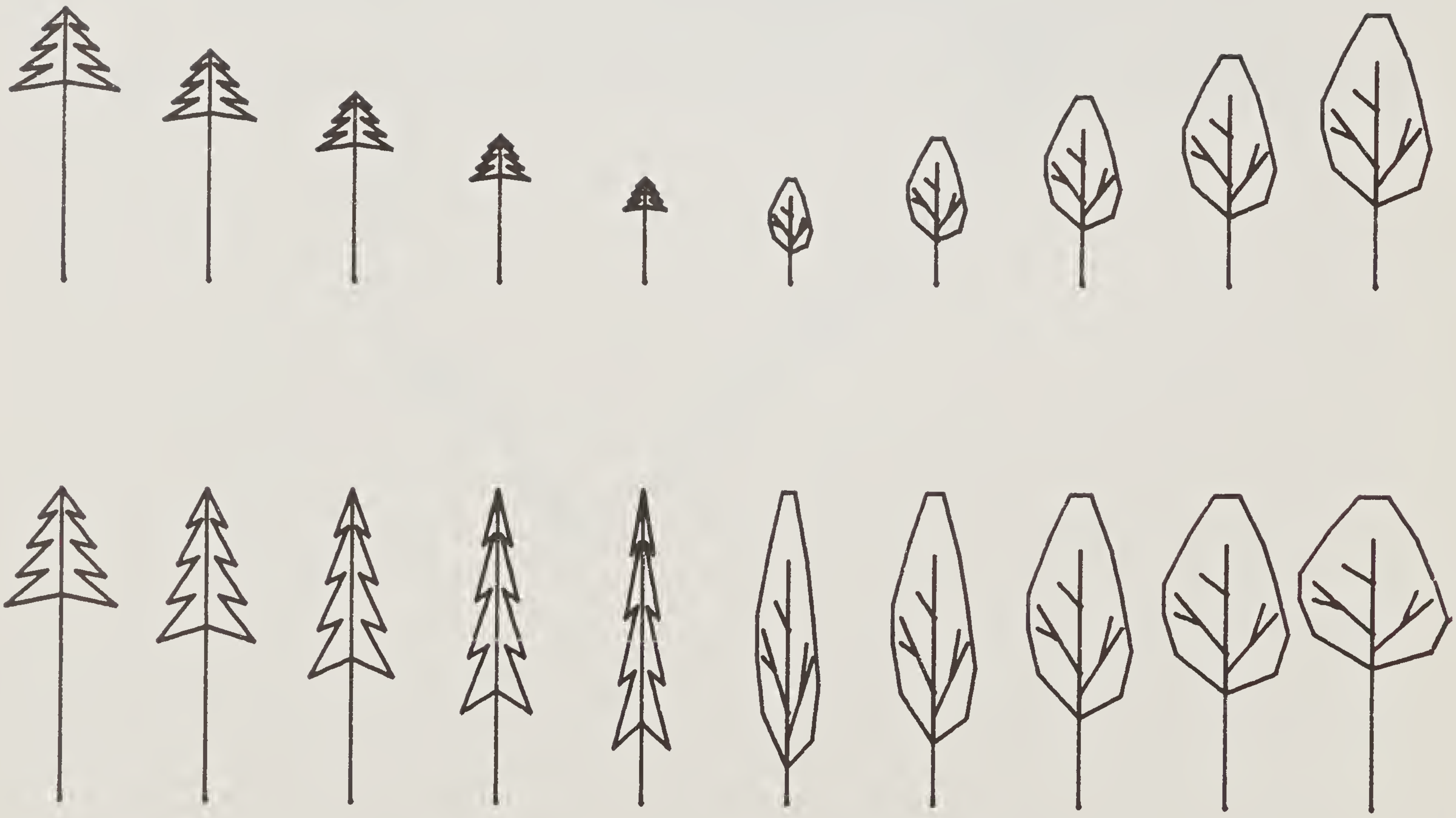


Figure B6-1. A range of conifer and hardwood crown heights, widths, and top ratios can be generated.

6. Tree Crown Data

When describing the boundaries of activity features, a tree figure description is paired with the terrain point coordinates. Considerable flexibility is possible in describing this tree figure, and liberties may be taken with the figure parameters to make possible the modelling of items other than trees. Generally, two tree figures are available -- a Conifer crown and a Hardwood crown -- although with some programming skills and a little imagination, other figures can be generated (see Case Study 9 for example). The user can control overall tree height, crown height (as a percent of tree height), and crown width to tailor the tree figures to species variations or local conditions. Figure B6-1 shows a range of crown sizes and shapes.

When describing terrain features from field traverse notes (see section B3), tree crown data is input at the main keyboard, in response to prompts appearing on the CRT. During description of the feature, the tree crown data can be altered by pressing the Special-Function Key [k0] CHANGE CROWNS on the main keyboard.

The CRT displays:

TYPE OF CROWN: CONIFER(C) OR HARDWOOD(H)?

Enter the appropriate response and press [CONT]. The CRT then displays:

OVERALL TREE HEIGHT (feet)?

Input the tree height and press [CONT]. The CRT then asks:

CROWN HEIGHT AS A PERCENT OF TREE HEIGHT?

Input this quantity and press [CONT]. The CRT then asks:

CROWN WIDTH (feet)?

Input the overall crown width and press [CONT]. This completes entry of tree crown data.

When describing terrain features by digitizing discrete points (see section B2), or from a Digital Terrain Model (see section B5), tree crown data is input at the digitizer numeric key pad, in response to prompts appearing on the digitizer 16-character display. During digitizing of the feature the tree crown data can be altered by pressing the Special-Function Key [ ] [fc] CHANGE CROWNS on the digitizer.

The digitizer displays, in a sequence taking about 6 seconds:

```
trEE SHAPE-----
1=COnIFEr------
2=HArDUOOD-----
1=COn     2=HrD
```

Respond with the proper code, using the digitizer number keys,

and [ENTER]. Then the digitizer displays:

[trEE Ht (Ft)]

Input the tree height in feet, and press [ENTER]. The display reads:

[toP rAtIo Pct]

Input the percent ratio of the tree's top, or crown, to the tree's overall height, then press [ENTER]. The digitizer then displays:

[toP SPrEAD (Ft)]

Input the overall spread, or width, of the tree's top, or crown, in feet, then press [ENTER]. This completes entry of tree crown data.

6. Tree Crown Data

1. Select Conifer or Hardwood crown type, using main keyboard or digitizer as appropriate.
2. Enter overall tree height (feet) in response to prompt.
3. Enter percent of total tree height taken by crown.
4. Enter crown width (feet).

7. Viewpoint Location

After describing an activity feature to be modelled, it is necessary to fix the coordinate position of the viewpoint from which the perspective depiction will be seen. There are several ways this may be done. Each way has advantages in certain situations. Note that the viewpoint may be located at any point in the planar surface represented by the plan view, and at any elevation. The user has complete freedom to reposition the viewpoint anywhere. Two geometric considerations should be kept in mind when selecting a viewpoint:

1. PERSPECTIVE PLOT produces imagery that is viewed at fairly small vertical angles. Since the image is held vertically for viewing, larger vertical angles produce outputs that must be viewed extremely obliquely. Results will be more satisfactory if such viewpoints -- locations very near the activity feature but at a greatly different elevation -- are avoided. Figure A3 describing the viewing orientation of the PERSPECTIVE PLOT graphic should give the user an appreciation for this limitation.

2. the PERSPECTIVE PLOT program makes no geometric adjustment for the earth's curvature. This is of little consequence for short-range project-oriented work (view distance under ten miles).

There are four ways in which a viewpoint may be identified. Upon branching to viewpoint selection, the user is presented with these four choices:

MODE 1 -- DIGITIZER
MODE 2 -- LINE-OF-SIGHT DISTANCE, AZIMUTH, SLOPE
MODE 3 -- CRT CURSOR
MODE 4 -- (X,Y,Elev) COORDINATES

The CRT displays:

VIEWPOINT MUST BE DESIGNATED BY ONE OF THESE MODES.
MODE NUMBER?

Select the desired mode number, followed by [CONT]. The procedure for each mode will be discussed separately.

MODE 1 -- DIGITIZER

This mode will not be offered if the feature boundary was described by traverse.

For boundaries that are digitized (section B2) or recalled from storage (section B4), the user is asked:

IS IT NECESSARY TO REORIENT THE MAP BASE (Y or N)?

Answer as appropriate. If yes, then the map axis will be

realigned, scale re-entered, and initial feature point digitized, in response to CRT prompts.

For features input from Digital Terrain Models (section B5), the type of map being used is identified and the axis alignment procedure is performed in response to CRT prompts.

The CRT displays:

DIGITIZE VIEWPOINT

Place the digitizer crosshair on the viewpoint and press the [D] key. For digitized or recalled boundaries (also DTM boundaries if the viewpoint is outside of the modelled terrain) the CRT asks for the elevation of the viewpoint. Type this value in (on the computer keyboard). The CRT asks:

VIEWPOINT IDENTIFICATION (UP TO 18 CHARACTERS)?

This can be any descriptive identification. It will appear in the upper right corner of perspective graphics. Program operation branches to selection of view direction and width-of-field (section B8).

MODE 2 -- LINE-OF-SIGHT DISTANCE, AZIMUTH, SLOPE

Often the critical viewpoint can be seen during field reconnaissance from some position on the activity boundary. If this position can be located and the line-of-sight back to the viewpoint described, the computer can calculate the viewpoint coordinates.

The first task is to identify the point from which the viewpoint sighting is made. This can be done in three ways:

DIGITIZER -- Simply digitize the boundary point from which the viewpoint sighting is made. On discrete-point models, the computer locates the closest boundary point and assumes that this is where the viewpoint sighting is made. On DTM-derived models, the computer can determine the elevation of the exact point digitized (if it is within the model!), so the point need not be exactly on a boundary.

BOUNDARY POINT NUMBER -- The user may enter the point number (obtained from the traverse notes printed out when a boundary is digitized) that identifies the location from which a viewpoint sighting is made.

CRT CURSOR -- The CRT displays the feature plan-view. A full-screen crosshair appears, showing as bright-green lines. Use the up, down, left, and right arrows on the keyboard to move the crosshair position. Fine movement is achieved by holding down the shift key. When the crosshair is located at the point from which the view-point sighting is made, press [CONT].

Having established the location from which the viewpoint is

sighted, the next task is to describe the line-of-sight. The CRT asks:

HORIZONTAL DISTANCE (ft), AZIMUTH, SLOPE (%) FROM BOUNDARY POINT TO VIEWPOINT?

Enter all three pieces of information, separated by commas, and press CONT . These values can be obtained by scaling distance from a map or aerial photo and taking compass bearing and clinometer slope. Or the values can be obtained to a much higher degree of accuracy using a transit or electronic rangefinder.

Type in the viewpoint identification -- anything up to eighteen characters -- in response to the CRT prompt. The program brances to selection of view direction and width-of-field (section B8).

MODE 3 -- CRT CURSOR

If the user does not have a specific viewpoint in mind, or has a viewpoint location that is dispersed in nature, the CRT cursor technique is quick and easy. For example, if a timber harvest proposal can be seen by ski-tourers who may be anywhere within several thousand acres north of the harvest area, a viewpoint located "somewhere off to the north" may be sufficient.

The CRT presents a block of instructions on using the CRT cursor to locate a viewpoint. The CRT produces a plan-view graphic of the activity feature (or a rectangle representing the DTM for certain outputs from DTM's). The display is held until the user presses CONT . The CRT displays:

IS SCALE SATISFACTORY (Y or N)?

If the scale is not small enough to include the desired viewpoint position, answer N CONT . The feature (or rectangle) is replotted to half the previous scale, centered on the CRT. Press CONT . The question is asked again. By this process, the scale can be successively reduced until the desired viewpoint position is included. Answer Y CONT when this condition is achieved.

The CRT displays the plan-view graphic. A full-screen crosshair appears, showing as bright green lines. Use the up, down, left, and right arrows on the keyboard to move the crosshair position. Fine movement is achieved by holding down the shift key. When the crosshair is located at the viewpoint, press CONT . The computer asks:

ELEVATION OF VIEWPOINT?

(unless working with a DTM). Enter the viewpoint elevation. The computer next asks for the viewpoint identification -- anything up to eighteen characters. The program branches to selection of view direction and width-of-field (section B8).

MODE 4 -- (X,Y,Elev) COORDINATES

The viewpoint location can be identified by coordinates. The origin of the coordinate grid -- point (0,0) -- is the lower left (southwest) corner -- the first point digitized upon axis alignment. Viewpoint coordinates can be determined by scaling distances from the origin. But the most frequent use of coordinate viewpoint description will be in production of sequential graphics from the same viewpoint.

Whichever viewpoint location mode is used, the viewpoint coordinates are printed under the viewpoint identification. Successive outputs -- alternative proposals, distorted-square terrain base, structures, vegetative cover, etc. -- can be superimposed. The graphics will collimate exactly only if the view is generated from the exact same viewpoint. Refer to the case studies, section C, for numerous examples of this approach.

The CRT asks, in succession:

X-COORDINATE OF VIEWPOINT?
Y-COORDINATE OF VIEWPOINT?
ELEVATION-COORDINATE OF VIEWPOINT?

Enter these values to the nearest foot or tenth. The computer next asks for the viewpoint identification -- anything up to eighteen characters. The program branches to selection of view direction and width-of-field (section B8).

7. Viewpoint Selection

1. Choose viewpoint selection mode 1, 2, 3, or 4 [CONT]
2. MODE 1 -- DIGITIZER
   a. Reorient map base or digitizer if necessary.
   b. Digitize viewpoint [D]
   c. Input viewpoint elevation if asked [CONT]
3. MODE 2 -- LINE-OF-SIGHT DISTANCE, AZIMUTH, SLOPE
   a. Identify point from which viewpoint is sighted, by (1) digitizer, (2) point number, or (3) CRT cursor.
   b. Input distance (horizontal), azimuth and slope of line-of-sight to the viewpoint (derived from field observations.)
4. MODE 3 -- CRT CURSOR
   a. CRT displays plan-view of feature. Press [CONT]
   b. IS SCALE SATISFACTORY (Y or N)? Answer as appropriate.
   c. If no, feature is replotted to smaller scale. Go back to step 1.
   d. If yes, use arrow keys to position crosshair at viewpoint, and press [CONT]
   e. Input viewpoint elevation if asked.
5. MODE 4 -- (X,Y,Elev) COORDINATES
   a. X-COORDINATE OF VIEWPOINT? Answer in feet [CONT]
   b. Y-COORDINATE OF VIEWPOINT? Answer in feet [CONT]
   c. ELEVATION-COORDINATE OF VIEWPOINT? Answer in feet [CONT]
6. VIEWPOINT IDENTIFICATION (UP TO 18 CHARACTERS)? Type this in [CONT]
7. Program branches to view direction, width-of-field (section B8).

8. View Direction, Width-of-Field

In the introductory remarks, section A, the PERSPECTIVE PLOT model was compared to imagery obtained with a camera. Imagine that the PERSPECTIVE PLOT camera uses 35mm film, like any Single-lens Reflex camera, and is mounted on a tripod. Imagine further that the PERSPECTIVE PLOT camera is equipped with a very expensive zoom lens, capable of adjustment for shots ranging from ultra-wide-angle to super-telephoto.

Section 7 -- Viewpoint Location -- deals with finding the point upon which to set the tripod. This section deals with aiming the camera in the proper direction and adjusting the zoom lens to the proper width-of-field.

There are three steps involved:

1. Swing the "camera" line-of-sight in a horizontal plane until it is pointing in the desired direction,
2. Adjust the width-of-field until the desired breadth of the activity feature is taken in,
3. Elevate or depress the line-of-sight from level to the desired vertical angle.

A page of instructions appears on the CRT each time view direction and width-of-field selection commences. The user is always asked (at the bottom of the CRT) if he would like a hard copy of the instructions. Respond Y or N $\boxed{\text{CONT}}$. The CRT returns to graphics mode, showing the activity feature under consideration and the selected viewpoint, in plan view. Special-Function Keys $\boxed{\text{k8}}$ - $\boxed{\text{k13}}$ become activated, as follows:

$\boxed{\text{k8}}$	$\boxed{\text{k9}}$	$\boxed{\text{k10}}$	$\boxed{\text{k11}}$	$\boxed{\text{k12}}$	$\boxed{\text{k13}}$
+45	+10	+1	-1	-10	-45

step 1. Point line-of-sight

To begin with, the line-of-sight, indicated by a dashed line, will be pointing north (azimuth = 0). Swing the line-of-sight clockwise or counterclockwise by increments of 1, 10, or 45 degrees. Each push of a Special-Function Key moves the line-of-sight the desired increment. It takes a moment to erase the old line-of-sight and replot the new one, so do not rush things. The line-of-sight azimuth is displayed in the lower left corner. It is possible to point the line-of-sight in any even-degree direction. When content with the line-of-sight direction, press $\boxed{\text{CONT}}$. The program will branch to...

step 2. Adust width-of-field

Two solid lines will appear, radiating from the viewpoint on either side of the line-of-sight. These describe the beginning width-of-field. The beginning half-angle is 30 degrees (60-degree total width-of-field), which, coincidentally, is equivalent to a 30mm focal-length lens on a 35mm camera. This fact is displayed in the lower right corner.

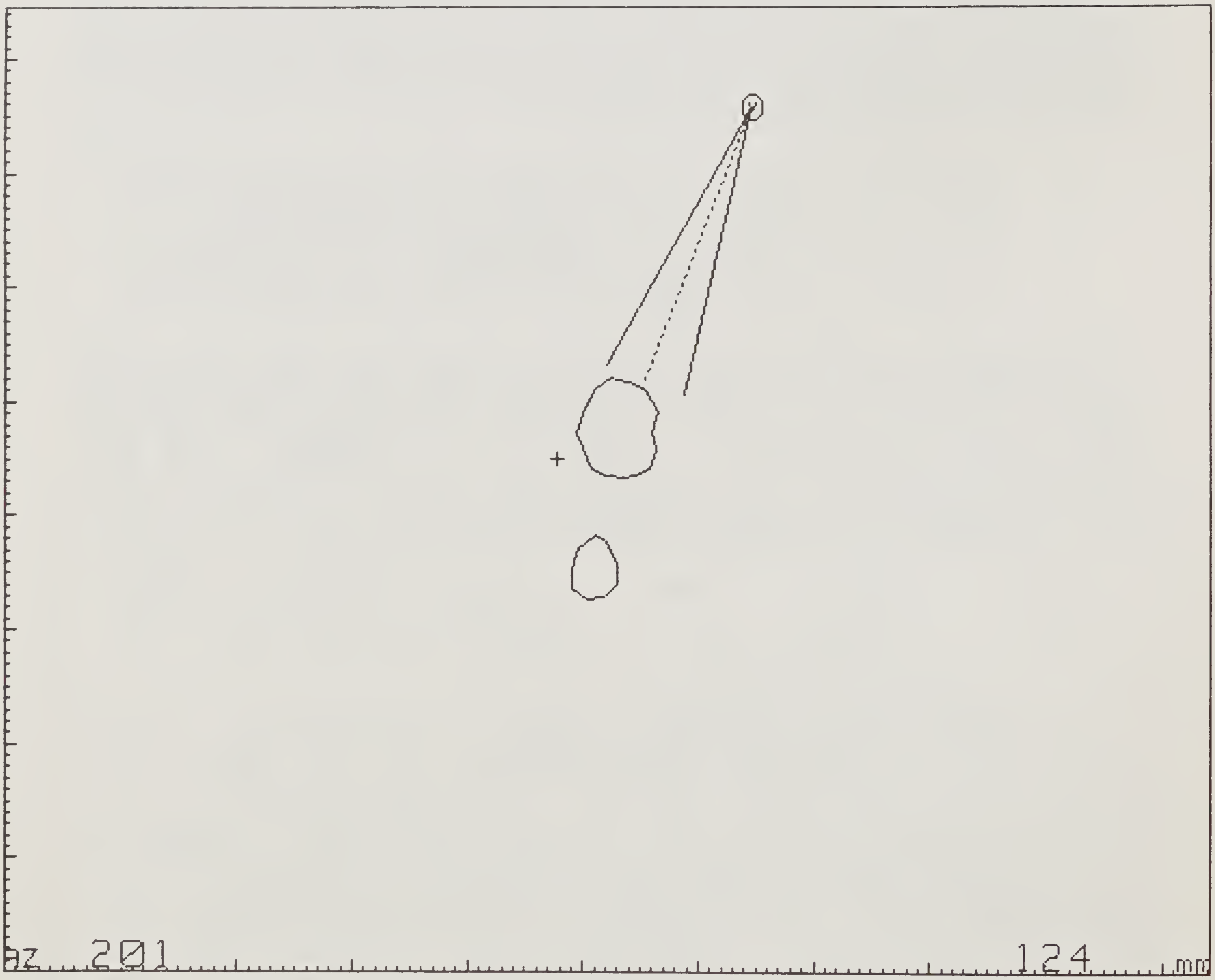


Figure B8-1. The view direction and width-of-field are selected while the project plan-view is displayed on the CRT.

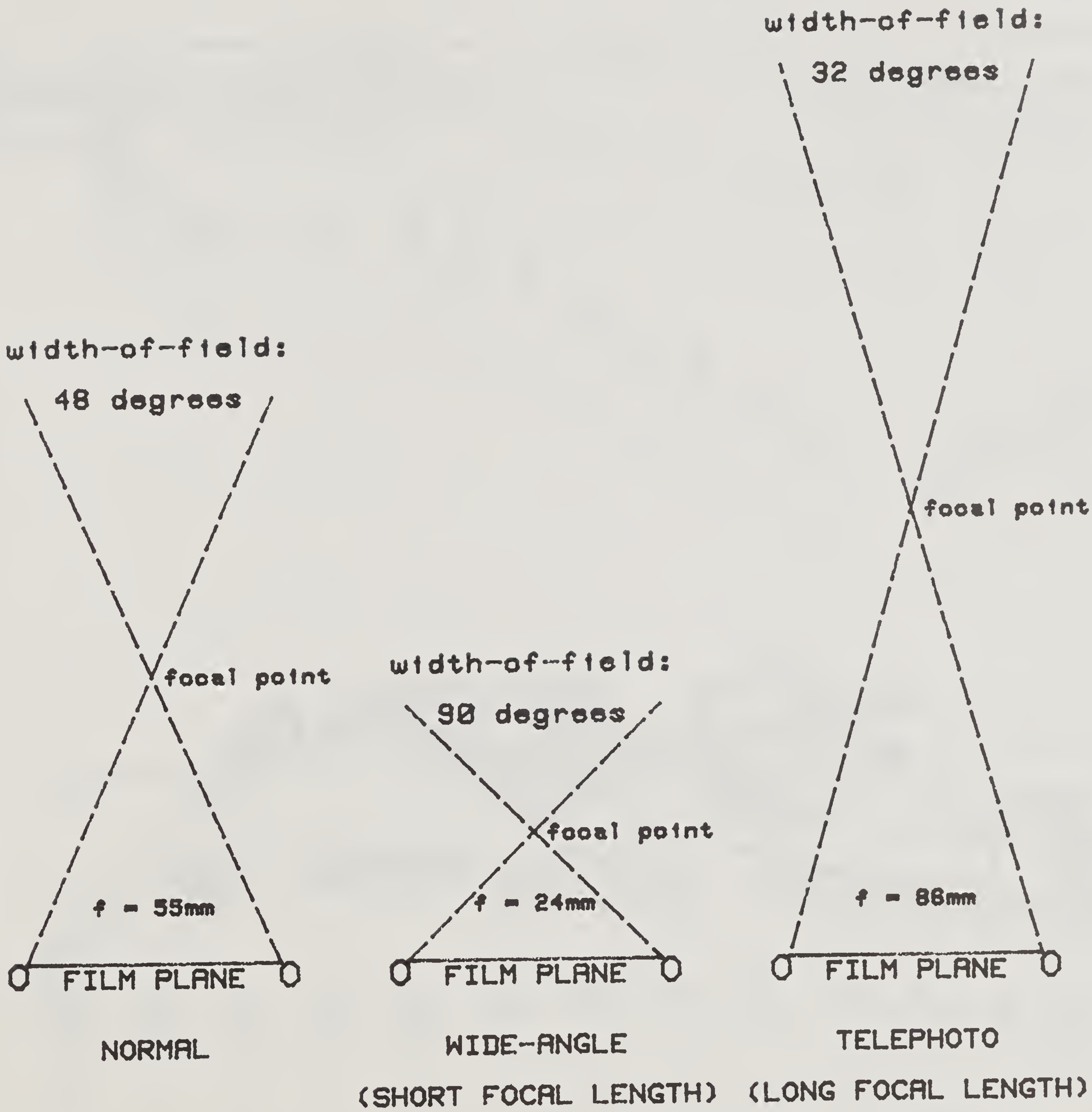


Figure B8-2. The inverse relation between angular width-of-field and focal length (or viewing distance) is illustrated. For PERSPECTIVE PLOT,

$$\text{Focal Length} = \frac{\text{Image Width}}{2 \text{ TAN Half-angle}}$$

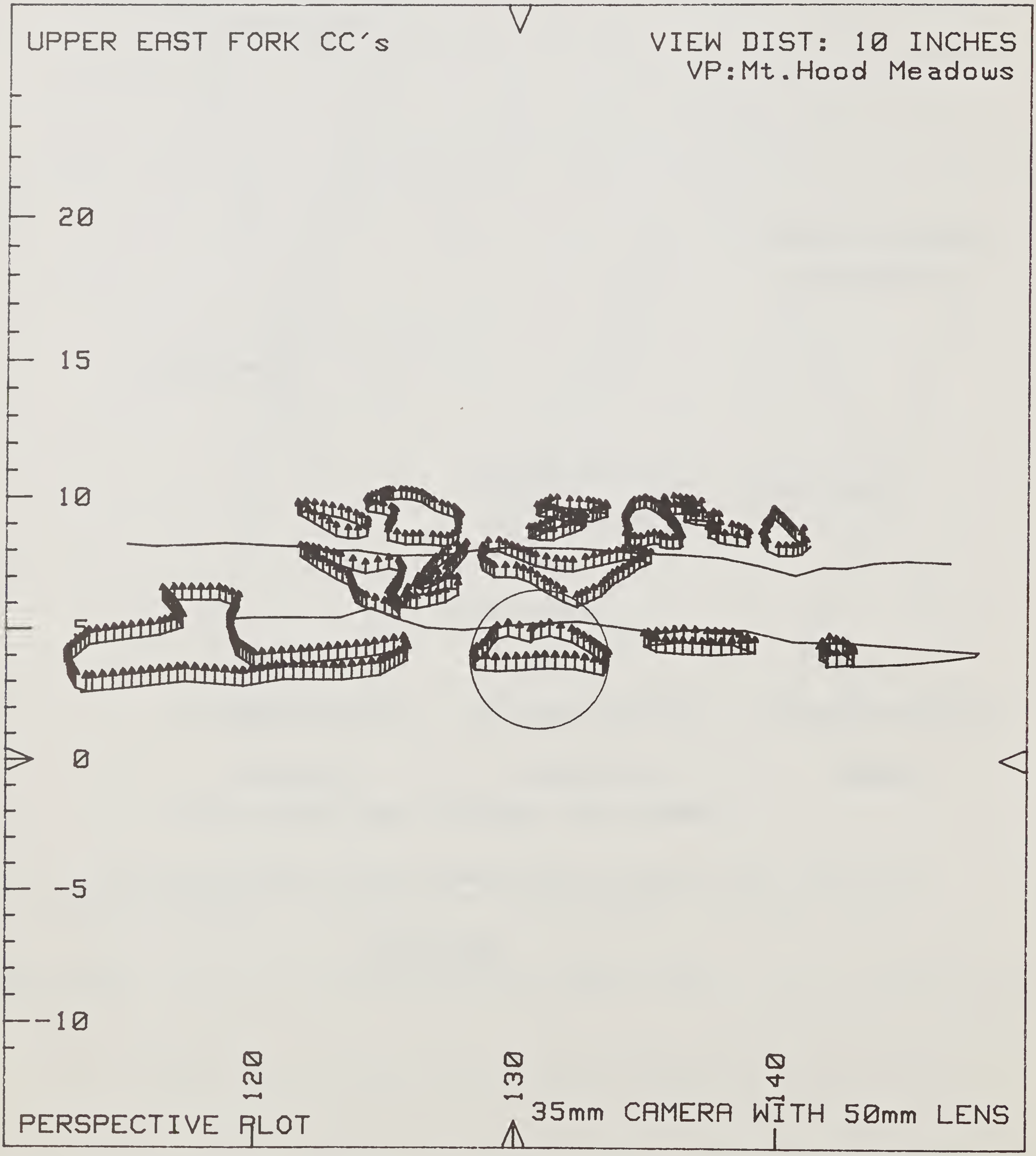


Figure B8-3. An array of existing clearcuts, proposed clearcuts, road centerlines and natural openings, seen in perspective view.

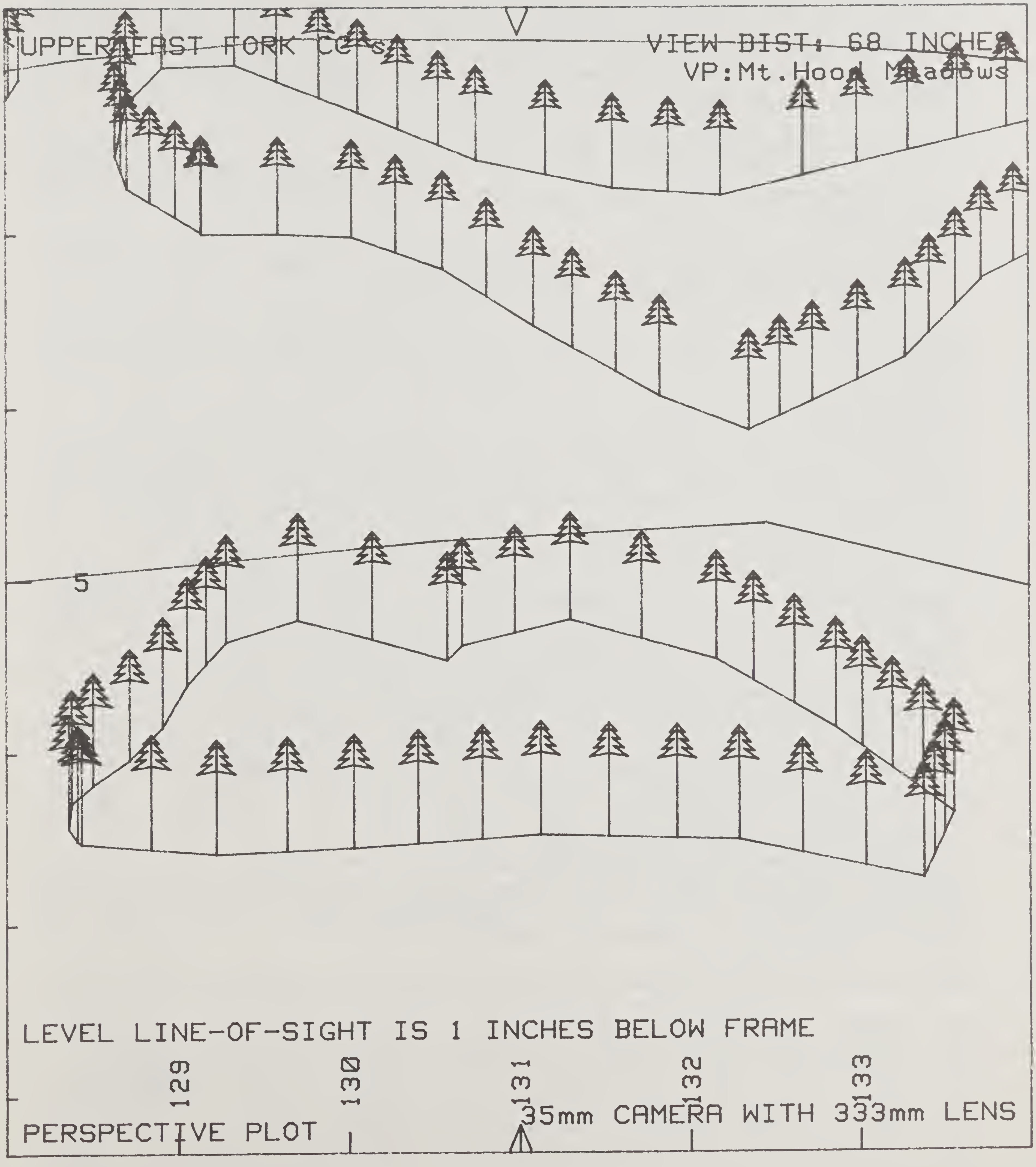


Figure B8-4. A close-up look at one boundary from figure B8-3.

Special-Function Keys $\boxed{k8}$ - $\boxed{k13}$ increase or decrease the half-angle by increments of 1, 10, or 45 degrees, allowing a range of width-of-fields between 2 degrees (a 1000mm super telephoto lens) and 178 degrees (a 1mm ultra-wide-angle fisheye lens). As the width-of-field becomes smaller, the focal length becomes greater; study figure B8-2 to appreciate this relationship. When content with the width-of-field, press $\boxed{CONT}$. After a moment, the program will branch to...

step 3. Select vertical angle

The computer calculates a weighted-average vertical angle and suggests this to the user in a CRT display similar to the following:

SUGGESTED VERTICAL ANGLE VIEWPOINT-TO-FEATURE IS -4.3 DEGREES
LINE-OF-SIGHT VERTICAL ANGLE DESIRED?

The user types in his choice of vertical angle, then presses $\boxed{CONT}$. If the width-of-field takes in the entire feature, the suggested vertical angle will adequately center the PERSPECTIVE PLOT image.

The view direction/width-of-field procedure can be interrupted and started over in the event of a change-of-mind. Press PAUSE then $\boxed{k6}$ CHOOSE OPTIONS (see section B14). Select Option 6 -- New View Direction and Width-of-field. If this option does not appear on the list, press $\boxed{k6}$ again, and the list will be reprinted, this time including Option 6.

The horizontal and vertical arc of a prior PERSPECTIVE PLOT graphic from the same viewpoint can be used to select a portion of a feature for isolated study or protrayal at telephoto magnification. As an example, consider figure B8-3. A large number of proposed harvest unit boundaries, together with a road centerline, have been modelled. The Logging Engineer may want to consider each unit separately. The circled unit is centered at an azimuth of 131 degrees, and will be entirely contained within a 3-degree half-angle. The median vertical angle is about 5 degrees above level line-of-sight. Figure B8-4 shows a PERSPECTIVE PLOT image oriented in this manner, showing the desired unit nicely centered.

After View Direction/Width-of-field selection, the program branches to the list of program branching option choices (see section B14). One of the PERSPECTIVE PLOT outputs may be selected and plot generation commences.

8. View Direction, Width-of-field
1. Obtain hard copy of instructions if desired.
2. Point the line-of-sight in the desired direction. $\boxed{CONT}$
3. Adjust the width-of-field to the desired angle. $\boxed{CONT}$
4. Type in the desired line-of-sight vertical angle. $\boxed{CONT}$
5. Go to CHOOSE OPTIONS, Option 6, to start over.
6. Use the horizontal and vertical arc of a prior plot to orient high-magnification images.

9. Distorted-Square Terrain Depiction

When working with a Digital Terrain Model (see section B5), it is possible to obtain a perspective depiction of the terrain itself. This serves as an excellent base for perspective depictions of activity features. The terrain depiction takes the form of the Digital Terrain Model's square grid, as distorted by elevational variations and perspective geometry. Hidden terrain is removed, and the same perspective frame surrounds the image.

Upon selecting the Distorted-Square Terrain Depiction output (see section B20), the user is asked to identify the type of plan-view base map he is using. The map is affixed to the digitizer and aligned carefully. Then a viewpoint is selected as described in section B8. During this phase, the entire DTM is represented as a rectangle in smaller-scale plan views. Select the desired output option from the menu offered -- either a single Distorted-Square Terrain Depiction or a stereo pair.

In the next phase, a full-size frame appears on the CRT. A radial pattern of astersiks is gradually produced (see figure B9-1). This is an overlay to the thermal-printer copy of the DTM graphic (figure B5-1). The asterisks identify terrain that is directly visible from the viewpoint, ignoring any screening offered by vegetation. The computer retains limiting vertical-angle information for the entire viewed field, however, so the upper portions of tall objects may be portrayed. Execution of the seen-area graphic averages about eight minutes, and terminates with an automatic graphics dump.

Drawing of the distorted-square terrain depiction commences with the appearance of the PERSPECTIVE PLOT frame on the CRT. If output to the flatbed plotter is desired, interrupt execution by pressing $\boxed{\text{PAUSE}}$. Then press $\boxed{\text{k14}}$ FLATBED PLOTTER and set up the plotter as described in section B15. Then choose the correct option from the menu. The seen-area graphic is not repeated; the computer remembers that it has been performed.

The distorted-square grid is produced by first plotting the south-to-north grid lines, beginning in the west, then plotting the west-to-east lines, beginning in the south. Some "noise", or error, may appear at ridge tops and in the very near foreground, but is seldom very severe. It is due to rounding-off and other computational considerations. CRT execution averages six minutes, while plotter execution takes about 20% longer.

If viewpoint selection was by digitizer and the distorted-square terrain depiction occured on the CRT, an opportunity is offered to "explore" the terrain in perspective. Press $\boxed{\text{CONT}}$ after reading the instructions, then press the digitize $\boxed{\text{D}}$ key and move the cursor about on the map base. The cursor position on the map will be identified on the CRT perspective depiction by a small flashing "+" symbol, which will move about on the graphic, vanishing into holes, beyond

```
VIEWPOINT: Scenic Overlook
        X-COORDINATE =  9081
        Y-COORDINATE =  137
     Elev-COORDINATE =  3388
      VERTICAL ANGLE =  1
```

* -- TERRAIN POINTS SEEN FROM VIEWPOINT, IGNORING VEGETATIVE SCREENING

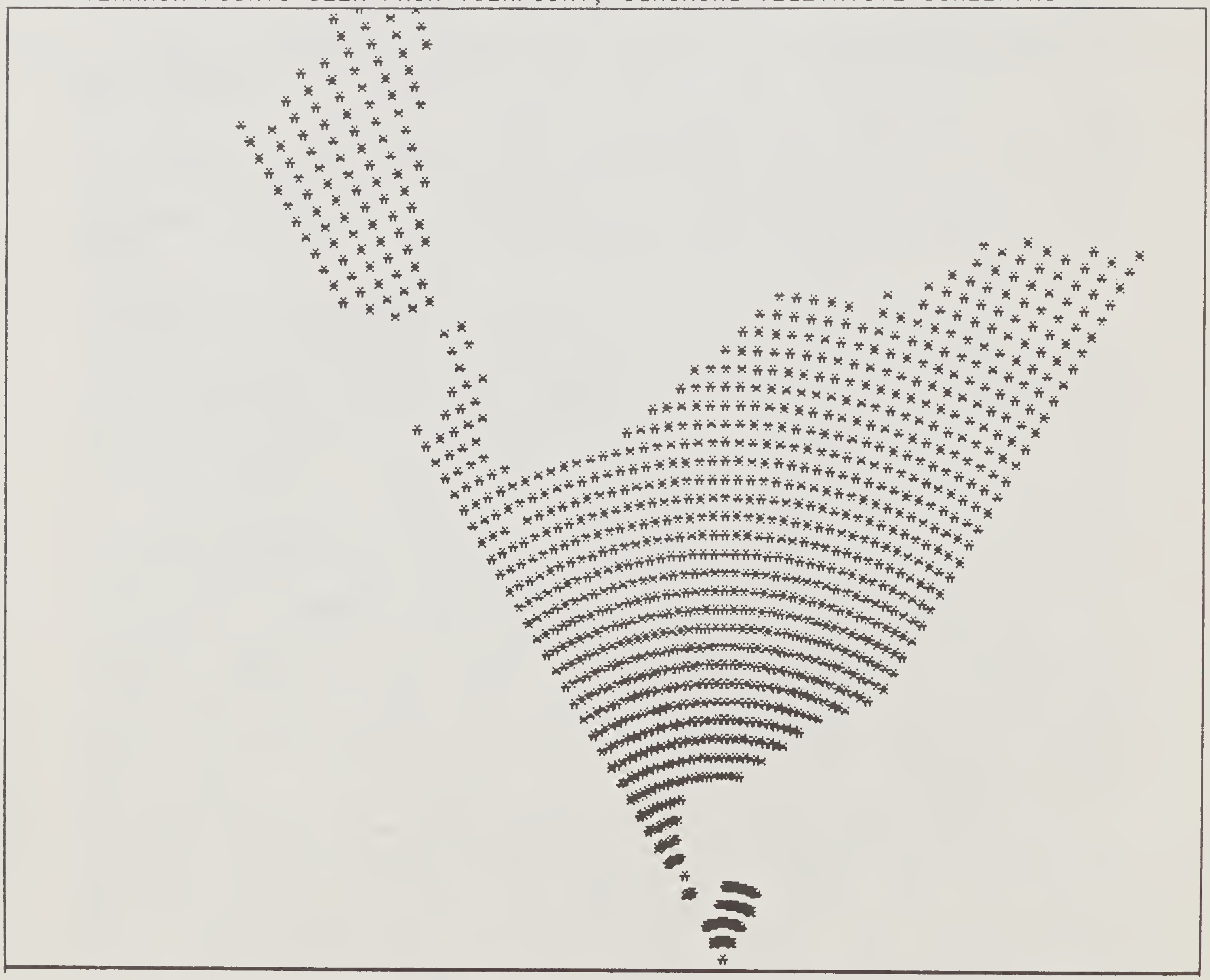


Figure B9-1. Once a viewpoint is identified, an overlay is produced that defines terrain not screened from view by topography.

ridges, and off the edge of the DTM. This is an excellent technique for identifying landforms in the perspective view and for trying tentative ground locations or boundaries. The moving "+" leaves no trail of its passage. Press $\boxed{fa}$ FINISHED on the digitizer to exit from this operation.

9. Distorted-Square Terrain Depiction
1. Identify viewpoint (section B7).
2. Select view direction, width-of-field (section B8).
3. CRT produces seen-area graphic.
4. CRT or plotter produces distorted-square terrain depiction.
5. If CRT, user may "explore" terrain.

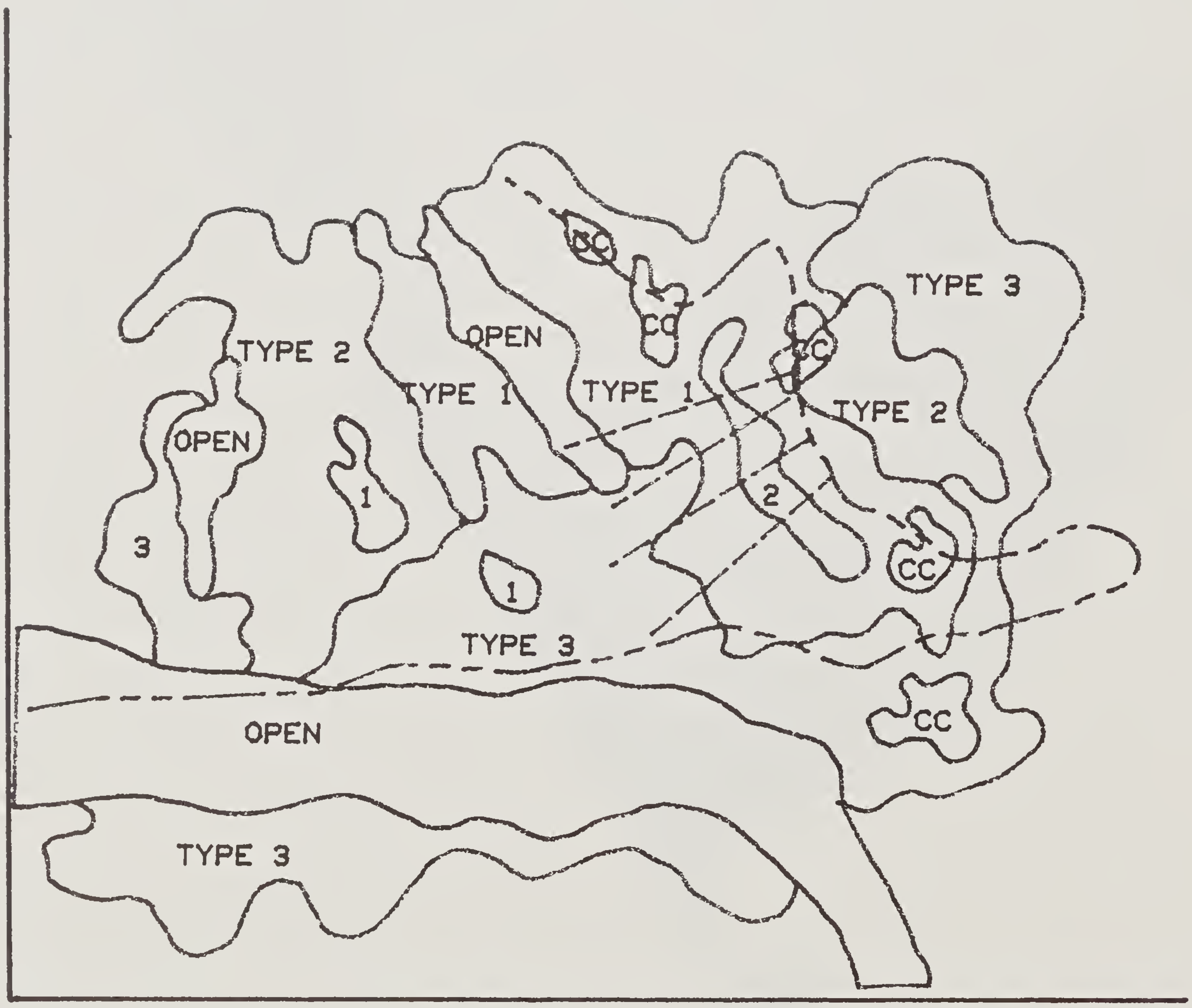


Figure B10-1. This timber type map identifies three distinct stands, plus unforested openings, roads, and skyline corridors.

10. Partialcut Timber Stand Boundaries

What is a partialcut simulation?

Partialcut timber harvest prescriptions or unbroken vegetation and surface textures can be portrayed by PERSPECTIVE PLOT. Case Studies 1, 6, 8 and 9 contain graphics that were created with this option. The partialcut simulation prototype program was written in 1977, and possessed the imaginative acronym SCOPE, standing for:

vi S ual management
C omputer
m O del for
P artialcut
timb E r stands

Although this title is subject to allegations of doubtful legitimacy, the author holds that a computer program's success is often a function of the catchiness of its name.

The user's first task is to describe the timber stand in plan view, using the digitizer. Up to three distinct timber types may be delineated which are subject to alteration by timber harvest activities. A fourth timber type is the peripheral, or surrounding, timber stand, which is not subject to alteration. Non-forested terrain can also be portrayed. This can be of two types:

* area-type features, such as unforested natural openings, existing clearcuts, clearcuts which are part of the planned timber harvest activity, bodies of water, etc.

* linear-type features, such as road right-of-way, stream channels, utility clearings, and skyline logging corridors.

The timber stand composition is described by entering the number of stems per acre, before harvest, and average tree height of four stand components:

Dominant crowns,
Codominant crowns,
Intermediate crowns,
and Suppressed crowns.

Later (in section B11), any partialcut harvest prescription is effected on the three managed timber types by entering the number of stems per acre remaining after harvest, and the perspective simulation of the timber stand is produced.

It should be apparent that fairly complex patterns of vegetation in a managed condition can be portrayed in perspective view. The visual elements of interest are:

* the degree of textural modification apparent in the contrast between partialcut and peripheral (uncut) timber stands,

* the patterns and forms of a mosaic of timber stands, vegetation types, and openings,
* the visual statement made by features associated with timber harvest or management,
* the comparative impacts of alternative intensities of management activities.

Although there are some imposing computational and data-management problems being addressed within the PERSPECTIVE PLOT partialcut simulation, the program is not difficult to run.

Only pure conifer stands are portrayed by the partialcut simulation. This is a reflection of the provincial limitations of the author, who lives and works among the coniferous forests of the Pacific Northwest. With some programming skills and some imagination, vegetation and textural graphics modifications are possible. Case Study 9 illustrates diverse vegetative patterns, such as tropical hardwoods, coconut palms, and pineapple plantation. Case Study 8 shows the replacement of vegetation symbols with shading on a lake surface. Mixed conifer-hardwood stands are another possibility.

The partialcut timber stand is produced upon a topographic base portrayed as a Digital Terrain Model. Turn to sections B17 -- B20 for information on DTM construction, storage, retrieval, and output selection.

Stand data must be stored on a PARTIALCUT DATA disk. This disk stores information for a single partialcut project, and must be prepared ahead of time. The program SETUP can be loaded from the PROGRAM disk and executed. Follow the simple instructions to set up a new disk as a PARTIALCUT DATA disk.

Timber stand boundaries should be drawn on the thermal-printer replica of the DTM, or on the base map from which the DTM was produced. Timber stand composition data should be collected. Figure B10-1 shows an example, ready to be affixed to the digitizer surface. Note that a timber stand type does not have to be a contiguous, single stand, and can have "holes" inside.

How are the timber stands described?

The user must first construct a Digital Terrain Model of the project area, or recall a DTM from storage (see sections B17 and B19). The program branches to the DTM output choice, described in section B20. Choose output 2 -- Partialcut simulation. After the program segment loads, the CRT displays:

```
INSTALL PARTIALCUT DATA DISK -- then press [CONT]
```

Remove the PROGRAM disk and insert a PARTIALCUT DATA disk. The CRT displays:

```
LAST PARTIALCUT STORED ON THIS DISK FOR SCOPE DEPICTION WAS-
(name of project...or blank)
DO YOU WANT TO DO FURTHER WORK WITH THIS PROJECT, i.e.:
     TRY A DIFFERENT CUTTING PRESCRIPTION
     SEE FROM A DIFFERENT VIEWPOINT
(ANSWER Y or N)?
```

Answer the question as appropriate. If Yes, the program will branch to generation of a perspective simulation (section B11). If No, a new partialcut project may be described. The currently-stored partialcut project is written over and lost.

The map base being used is identified and aligned on the digitizer. Be particularly careful in accurately locating the southwest (lower left) corner.

Upon starting a new partialcut project, the computer asks:

PARTIALCUT PROJECT NAME (up to 60 characters -- stops here->|

Type in the project name and any identifying information. The CRT then asks:

HOW MANY DISTINCT TIMBER TYPES OR TREATMENT ZONES(1, 2, or 3)?

Once again, these are timber stand types whose composition or proposed harvest treatment are distinct enough to make a perceivable textural difference. A type need not be a single contiguous block.

The computer displays brief instructions about the digitizing of the first timber stand type boundary. As soon as these have been read, press CONT and digitizing begins.

The PERSPECTIVE PLOT program uses a feature of the HP9845 hardware in a unique manner to store a great mass of information. Consider the graphics imagery on the CRT -- a "raster-scan" device which produces pictures by lighting discrete phosphor dots on the TV screen. The computer retains a numerical record of which dots are "on" in a particular graphic image. It is this graphics "buffer" that makes possible the storage of a DTM graphic, such as figure B5-1, or the "dump" of any CRT graphic image to the thermal printer -- another device that produces dot-matrix imagery. Since the CRT has more than a quarter-million dots, the graphics buffer represents a medium for portrayal, manipulation and storage of a large amount of timber stand data. In fact, each dot can represent a possible tree location within a given timber stand type. Combining this graphics buffer information with the stand composition information and a random-number generator, a timber stand simulation that is convincingly random is produced.

It should be apparent that the task is to draw the boundary of a timber stand type, then turn on all the dots -- the potential trees -- within the boundary. While a five-year-old child with a purple crayon can easily color-in a figure, this procedure is not so easy for a $50,000 computer. Therefore, some points must be observed so that timber stand type boundaries may be filled in correctly:

* All boundaries must be portrayed as closed figures.
* Boundaries cannot cross over themselves (like a figure-eight).
* A boundary must not go outside the DTM rectangle.
* The starting-point for boundary digitizing should be along a "side" of the boundary, rather that at an extreme point in the Y (north-south) direction.
* Finish digitizing a fraction of an inch from the starting-point, and let the computer close the figure.

The digitizer enters the continuous-sampling mode. Press the D

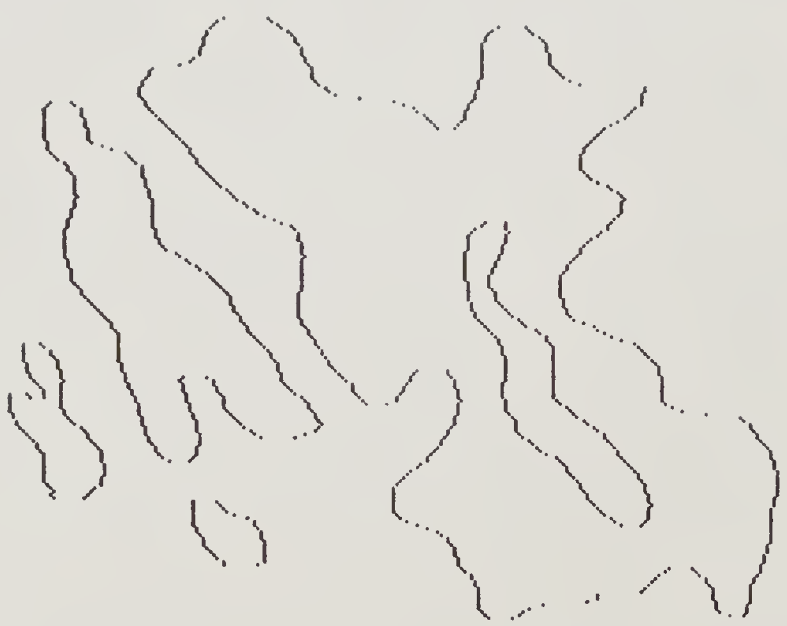


Figure B10-2. Timber Type 1 from figure B10-1 has been digitized.

key to start digitizing, and move the cursor slowly around the boundary. Stop a fraction of an inch before reaching the starting-point, by again pressing $\boxed{D}$. Indicate that digitizing is finished by pressing $\boxed{fa}$ FINISHED. The figure boundary, shown on the CRT at the scale of the DTM graphic, will be closed. The CRT then asks:

WANT TO DIGITIZE ANOTHER FIGURE (Y or N)?

Islands of different timber stand types (1, 2, 3, or peripheral) within blocks of the current timber type must be digitized as "another figure." Unforested patches within blocks of the current timber type will be handled later, so they need not be digitized as "another figure." Separate, unattached blocks of the current timber type are digitized as "another figure." Answer the question appropriately and continue digitizing until all boundaries for the current timber type are digitized. Figure B10-2 shows the boundaries of Timber Type 1 from figure B10-1, as they appear on the CRT after digitizing.

Upon responding N $\boxed{CONT}$ to the prompt for digitizing another boundary figure, the computer fills-in the boundary. The CRT displays this fascinating procedure, so that the user can be certain the fill-in is done correctly. It is very apparent when the fill-in is done incorrectly! See figure B10-3. Upon completion, the CRT asks:

HAVE BOUNDARIES BEEN PORTRAYED AND FILLED IN CORRECTLY(Y or N)?

A N $\boxed{CONT}$ answer will cause the graphics to clear, and digitizing will have to be redone. Review the rules and obey them carefully until success is achieved (see figure B10-4). A Y $\boxed{CONT}$ answer causes the timber stand data contained in the graphic to be stored on the disk (this takes about 30 seconds). The computer next displays the maximum total number of trees per acre that can be recorded, in preparation for input of timber stand composition information. Since there are 254,800 dots on the CRT, the maximum number of trees per acre is this number divided by the total acreage of the DTM. For example, if the DTM consists of 2000 acres, the maximum number of stems per acre will be 254,800/2000, or 127. Since production of a partialcut simulation graphic is quite time-consuming, the user should consider a proportional reduction in stems per acre. This technique should allow a protrayal of textural differences in a qualitatively correct fashion, and will speed up the plotting output.

The computer asks for number of stems per acre before harvesting and average tree height for each component of the timber stand. The data inputs are displayed and the user is asked to verify that they are correct. Then the stand composition information is stored on the disk.

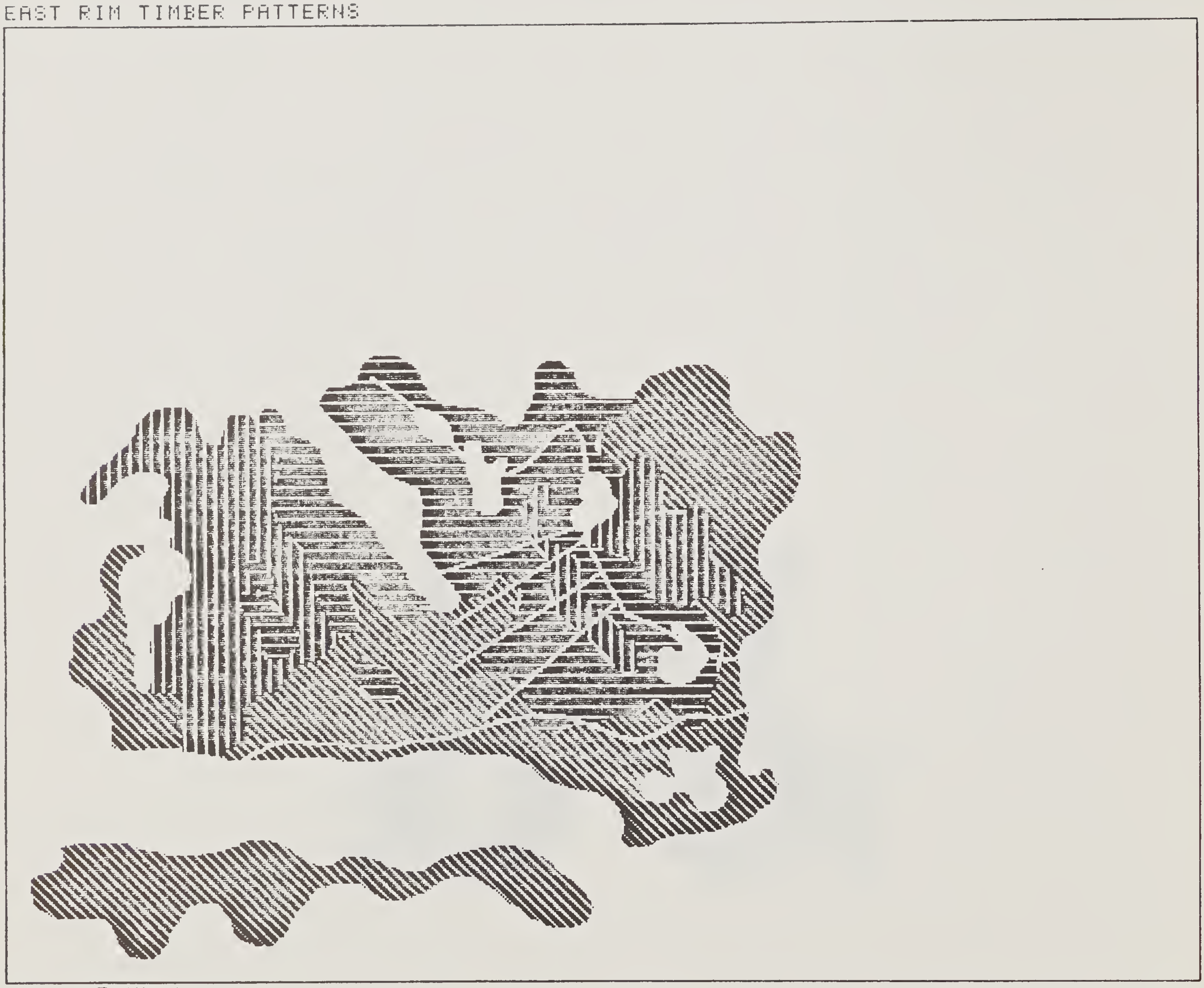
The boundary-digitizing and stand composition information sequence is repeated for each timber stand type.

Area-type unforested openings are digitized next. The procedure is identical to the timber stand boundary procedure, except that dots in the filled-in boundary represent "lack-of-trees", or nonforested terrain.

Figure B10-3. The computer has attempted to fill-in the Timber Type 1 boundary, and has not been successful due to careless digitizing.

Figure B10-4. Timber Type 1 boundary has been redigitized and filled-in correctly.

EAST RIM TIMBER PATTERNS



```
==    STAND 1
||    STAND 2
\\    STAND 3
..    OVERLAP (taken as lower-numbered type, i.e. overlap between 1
              2 is taken to be type 1)
```

Figure B10-5. After all timber types and unforested areas have been digitized, a combined graphic is produced which identifies the types by cross-hatching.

Linear-type unforested openings are produced in slightly different fashion. The user inputs the width (in feet) of a linear opening, and digitizes along the centerline in continuous mode. The digitizer cursor must be moved <u>very slowly</u>! Watch the CRT for feedback on how fast to go. Long, straight linear openings (such as skyline corridors) can be digitized by going to single-sampling and digitizing the endpoints. Digitize each linear-type opening separately by continuing to say Y [CONT] when asked:

DIGITIZE UNTIMBERED OPENINGS (LINEAR)(Y or N)?

Linear features are colored-in by the CRT's moving a rotating rectangle along the path of the centerline. It is necessary for the linear feature to be solidly colored-in -- any "off" dots within the strip may show up as a tree in the perspective depiction. The computer will have trouble only with linear unforested features that are very wide, relative to the size of the DTM. The user should consider delineating these as area-type unforested features.

When all unforested features are correctly portrayed, the information is stored on the disk.

The computer calculates a "combined graphic," which displays the complex of timber stand types and unforested features. Unforested features in the peripheral timber type do not show in the combined graphic, but are correctly stored on the disk. The several timber types are identified by crosshatching. Figure B10-5 shows the combined graphic resulting from digitizing the complex of timber stands in figure B10-1. The combined graphic is to the same scale as the DTM, and can be used as an overlay.

Obtain a graphics dump, if desired, and press [CONT]. The CRT prompts:

REPLACE PROGRAM DISK IN DISK DRIVE UNIT--then press [CONT]

The program moves on to the partialcut depiction segment (see section B11).

10. Partialcut Timber Stand Boundaries

1. Obtain a DTM by constructing or retrieving from storage.
2. Mount map on digitizer.
3. Install PARTIALCUT DATA disk in disk drive.
4. For each timber type, digitize boundaries.
5. Redigitize if fill-in is improperly performed.
6. Enter timber stand composition information.
7. Enter peripheral timber stand composition information.
8. Digitize area-type unforested openings.
9. Digitize linear-type unforested openings.
10. Computer sequentially produces and displays combined timber stand graphic.
11. Replace PROGRAM disk and press [CONT].

DESCRIPTION OF TIMBER TYPES AND CUT PRESCRIPTION

Average tree Height (ft)	DOMINANT	CODOMINANT	INTERMEDIATE	SUPPRESSED
Periphery	185	0	0	45
Type 1	180	135	85	35
Type 2	85	0	0	0
Type 3	200	0	0	45
Trees per acre				
-before harvest:				
Periphery	30	0	0	10
Type 1	8	12	6	2
Type 2	25	0	0	0
Type 3	10	0	0	10
-after harvest:				
Periphery	30	0	0	10
TYPE 1	4	4	0	0
TYPE 2	18	0	0	0
TYPE 3	5	0	0	0

Figure B11-1. A timber stand data table. Information describing the stand before partialcutting was input when the boundaries were digitized (see section B10). The residual stand description (after partialcutting) may be revised repeatedly, in a sequence of perspective simulations.

11. Partialcut Timber Stand Depiction

The PERSPECTIVE PLOT partialcut timber stand depiction allows the assessment of textural changes when timber stands are harvested under partial removal regimes. The program will branch to this section once the user has described a complex of timber types on a PARTIALCUT DATA disk (see section B10).

The CRT first prompts the user to:

INSTALL PARTIALCUT DATA DISK IN DISK DRIVE--then press [CONT]

The CRT displays the stand data table as input onto the PARTIALCUT DATA disk in section B10 -- tree heights and stems per acre for all crown classes in each timber type. The CRT displays the question:

WANT TO DEPICT PERIPHERAL TIMBER (Y or N)?

The peripheral timber can illustrate the contrast between unmanaged and harvested stand texture, but may also increase plot execution time. So the choice to include or exclude these areas is left to the user.

The CRT displays, for every crown class in timber types 1, 2, and 3 having some stems per acre before harvest, a prompt similar to this:

TYPE 1 DOMINANTS PER ACRE BEFORE HARVEST: 15 AFTER HARVEST:__?

It is here that the user can simulate any desired stand treatment, by describing the residual stand after partialcut timber harvest.

When all responses are complete and the finished stand table is displayed, the CRT asks:

IS PARTIALCUT PRESCRIPTION CORRECT (Y or N)?

If yes, the stand table is printed. The user selects a viewpoint, as described in section B7, and view direction and width-of-field as described in section B8. The computer CRT enters graphics mode and produces a seen-area overlay, exactly as described for the distorted-square terrain depiction in section B9 (see figure B11-2). Upon completion, the user is asked to position the full-screen crosshairs at the lower-left and upper-right corners of a box enclosing the maximum area to be included in the partialcut simulation. This is an opportunity to decrease the area being simulated, and consequently the plot execution time. A box is drawn around the area to be simulated (see figure B11-2), and the graphic is dumped. The options menu is presented. Invoke the flat-bed plotter if desired (see section B15). Select the perspective depiction option and production of the graphic commences. Do not disturb the disk drive unit, as information is periodically obtained from the PARTIALCUT DATA disk. The user can turn to other tasks while the computer churns away on the graphic.

As has been mentioned, partialcut plot execution is

```
VIEWPOINT:           Road 1357A
        X-COORDINATE =  10219.6
        Y-COORDINATE =  188.4
     Elev-COORDINATE =  3470.2
      VERTICAL ANGLE =  4  DEGREES
```

* -- TERRAIN POINTS SEEN FROM VIEWPOINT, IGNORING VEGETATIVE SCREENING

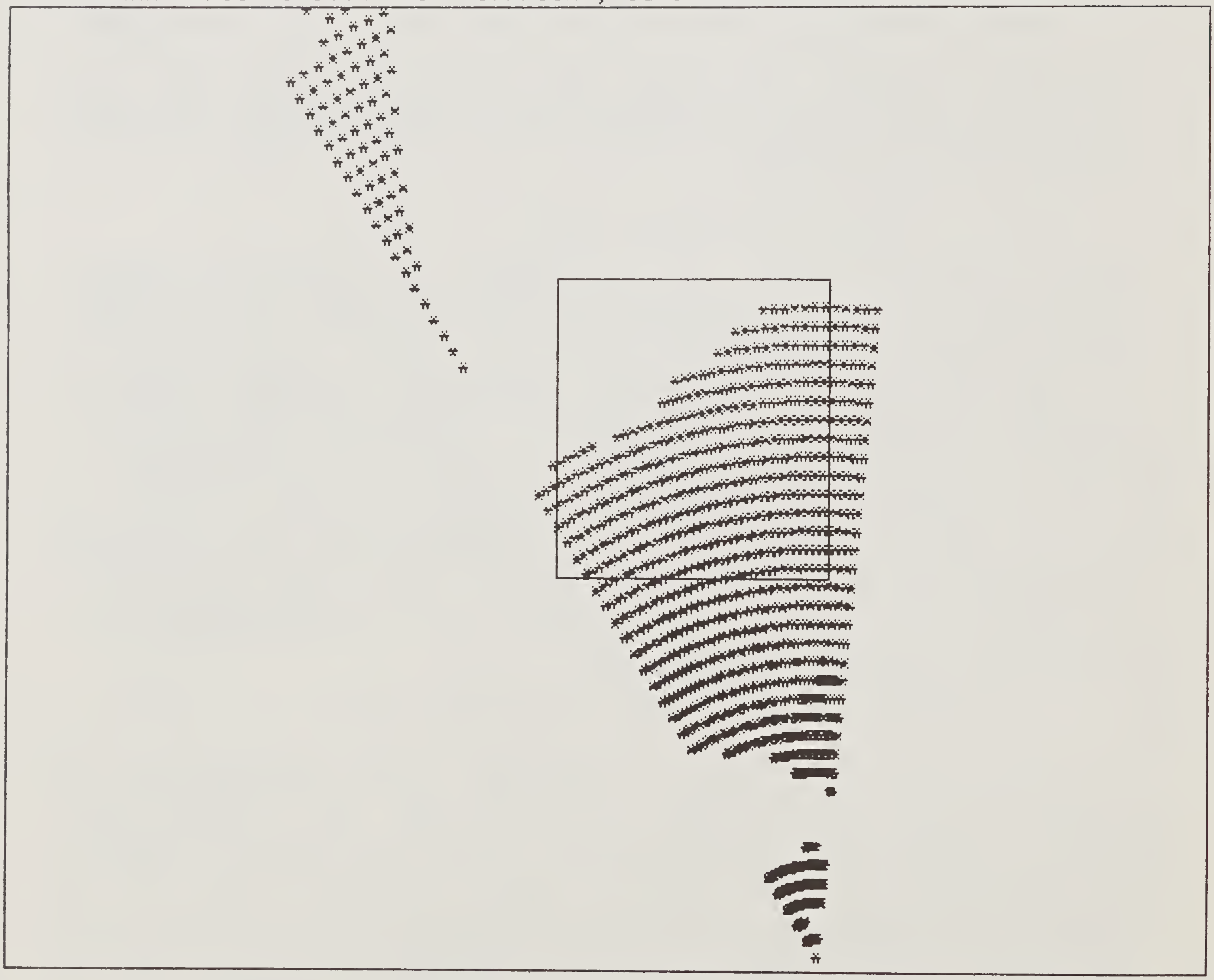


Figure B11-2. After having determined terrain that is visible from the viewpoint, the computer allows the user to delineate a reduced area (rectangle) for partialcut perspective simulation.

time-consuming! The times required for plot execution for several figures are tabulated below:

figure	approx. execution time
C1-3	55 minutes
C6-1	30 minutes
C8-1	50 minutes
C9-1	2 hours 45 minutes

Execution time is limited by input/output messages to the plotter and by that device's physical limitations, as well as by the imposing computational problems being addressed in a random simulation of this magnitude. No appreciable gain would be experienced on a major computer mainframe, and the user would have time-sharing expenses, graphics limitations, and an "unfriendly" computer environment to contend with. Nonetheless, long execution times mean that the user should exercise judgment in the matter of partialcut simulations, rather than experiment with numerous alternatives.

The plotter paper may become saturated with ink if many tree figures are plotted on top of one another. If this happens, the paper may break down and the plotter surface will be stained (clean with mild soap and very little water). Plotting on enamel-finish paper, mylar, or acetate (using special acetate pens) will alleviate this problem.

Press CONT after the plot is finished. The CRT displays the branching options menu. If the option selected moves out of the current program segment, the CRT displays:

REPLACE PROGRAM DISK IN DISK DRIVE UNIT--then press CONT

11. Partialcut Timber Stand Depiction

1. Install PARTIALCUT DATA disk
2. In response to prompts, complete the stand data table
3. Select Viewpoint (see section B7)
4. Choose View direction, width-of-field (see section B8)
5. CRT produces seen-area overlay
6. Locate corners of a box enclosing area to be portrayed
7. Invoke flat-bed plotter, if desired
8. Choose option -- if perspective graphic, computer produces graphic, requiring from a few minutes up to several hours.

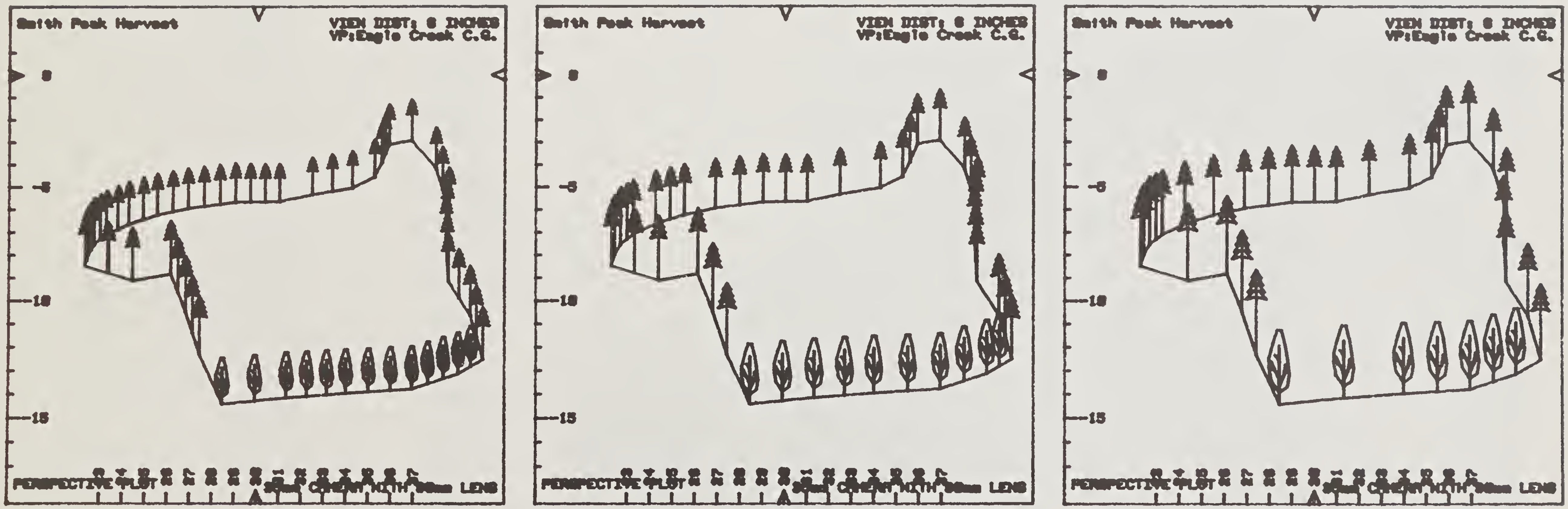


Figure B12-1. Tree Growth Increment. This series illustrates the change in perceived form and scale relative to tree height, as the boundary timber increases in overall height with time.

12. Tree Growth Increment

Selection of Option 3 -- Tree Growth Increment -- enables the manager to assess the visual effect of altered tree heights. The option is available for all discrete-point timber-harvest features (see sections B2, B3, and B4) and for timber harvest features obtained from a Digital Terrain Model (see section B5).

Upon selection of the Tree Growth Increment option, the user is asked:

AMOUNT OF GROWTH DESIRED (feet)?

A numeric response is input, followed by [CONT]. All trees around a feature boundary are portrayed at the height originally input (see section B6), plus the specified growth increment (the increment can be negative, to reduce tree height -- minimum height = 0). Boundary with trees originally input at zero height will continue to show no tree crowns, i.e. the growth increment will not be added to locations where no trees were originally portrayed, allowing the preservation of treeless features such as road centerlines. Repeat the Tree Growth Increment option with an input of zero to negate the effect.

Use Tree Growth Increment option to assess the change in perceived form and scale of a forest opening, as the boundary trees grow over time. Also, the option might be used to test the sensitivity of the opening's form and scale to errors in the estimated tree height.

12. Tree Growth Increment

1. Select Option 3 from list of options.
2. Type in desired growth increment [CONT]
3. Repeat, with a growth increment of 0 to return to original tree heights.

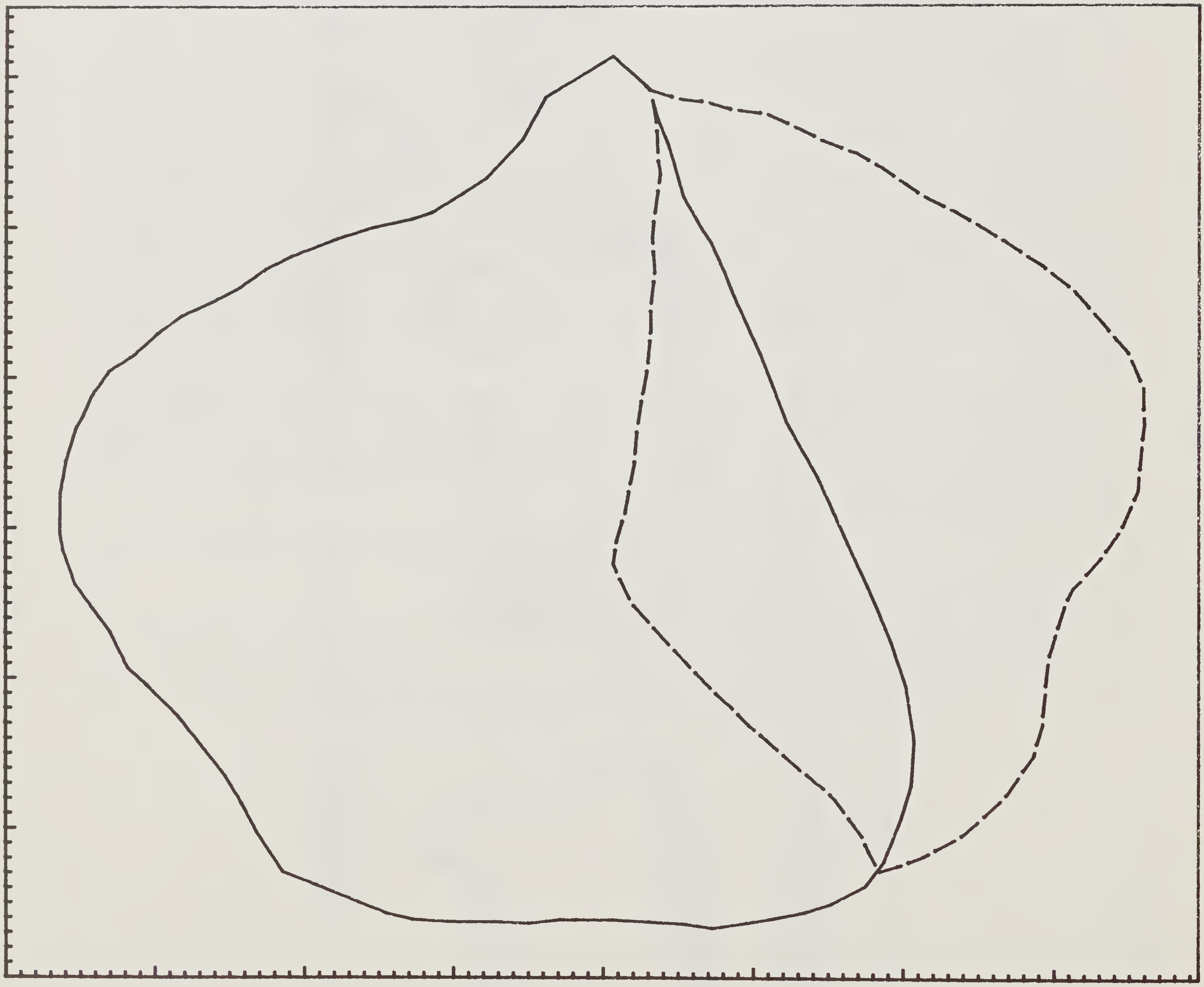


Figure B13-1. Plan-view of alternate boundary locations for a proposed timber harvest area.

13. Feature Alteration

Boundary-type features, such as the proposed clearcut timber harvest activity shown in figure C1-2 of Case Study 1, may be altered when input as a digitized discrete-point model. That is, segments of boundary may be deleted and redigitized, avoiding the necessity of redoing the entire boundary in order to display an alternate proposal.

Boundary description proceeds so rapidly with the Digital Terrain Model technique (see section B5), it was not felt necessary to provide for boundary alteration.

Boundary alteration is not available when working with traverse boundaries or retrieved boundaries.

To alter a boundary feature, the user must first delete a portion of the boundary, then replace the deleted portion. The CRT displays instructions for performing these acts, and offers the opportunity to obtain a hard copy.

Delete a segment of boundary by digitizing the endpoints of the segment, using the topographic map base, undisturbed from boundary input. The CRT displays:

DIGITIZE ONE END OF SEGMENT TO DELETE

The computer pauses a moment to locate the boundary point closest to the point digitized. Then the CRT displays:

DIGITIZE OTHER END OF SEGMENT TO DELETE

After locating the boundary point closest to the second point deleted, the computer checks to be certain that both points are on the same boundary feature. If they are not, a warning is displayed and the user is given the chance to try again. If they are, the CRT plots the boundary features, then erases the segment between the lower-numbered and the higher-numbered endpoints. It is posible that the erasure will proceed the wrong way around the boundary of closed figures. Or it is possible that the boundary erasure will be totally incorrect. The CRT displays:

HAS ERASURE BEEN PERFORMED CORRECTLY(YES, NO, OR WRONG WAY)?

Respond appropriately (just the first letter -- Y, N, or W -- is sufficient). A YES answer will cause the segment to be permanently deleted from the boundary data, and the program will branch to the replacement routine. A NO answer will send the user back to start over, redigitizing the endpoints of the segment to delete. A WRONG WAY answer will cause a replot of the boundary feature, and erasure moving the other way around a closed figure, after which the user is again asked if erasure was performed correctly. The user is then asked if he wishes to erase additional segments, and if he wishes to replace the segments deleted.

The boundary segment replacement should be digitized as an

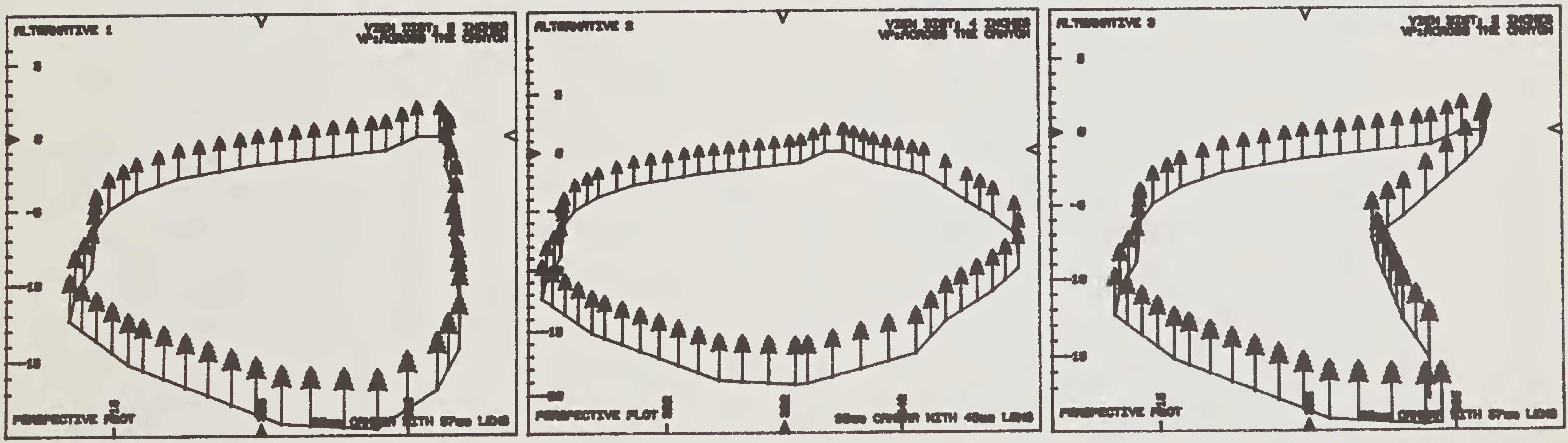


Figure B13-2. Perspective views of alternate boundaries shown in figure B13-1.

open feature. It is the user's responsibility to connect up the endpoints of the replacement segment, both in plan position and in elevation. Errors in accomplishing this will leave gaps or discontinuities in the perspective features.

13. Feature Alteration

1. Digitize both endpoints of segment to delete, in response to prompts. Both points must be on same feature.
2. Answer whether erasure was performed correctly -- YES, NO, or WRONG WAY (Y, N, or W is sufficient).
3. Erase additional segments if desired.
4. Replace erased segments by digitizing altered boundary as an open feature.

14. Choose Program Branching Option

At numerous points in the PERSPECTIVE PLOT program, the user is offered a choice of things he can do next. Some of these "branching options" are different graphical outputs or different viewpoint geometry. Other branching options route the program back to various activity feature input methods.

It is possible to interrupt the program and re-route through the choice of branching options. This may be done in almost any phase of the program. Special-Function Key [k6] CHOOSE OPTIONS offers immediate access to the Program Branching Options "menu" in the current program segment.

The following section will describe each option available at one or more point in the PERSPECTIVE PLOT program. Where the option is offered and where the option is documented will be discussed.

PERSPECTIVE VIEW

The perspective view output is the basic oblique-view graphic of the PERSPECTIVE PLOT program. This output is offered for all discrete-point boundary features (sections B2, B3, B4), Digital Terrain Model boundary features (section B5), distorted-square terrain depiction (section B9) or partialcut timber stands (section B11). Section A discusses the geometry of the perspective view graphic, as seen in figure A2.

STEREO PAIR

This output option enables the user to view the perspective depiction in three dimensions, using a mirror stereoscope. The stereo view is produced by the computer's moving right and then left of the viewpoint a distance proportional to the width-of-field, to produce stereoscopic separation. Press [k14] DUMP GRAPHICS after each plot to obtain hard copies. Better yet, use the flatbed plotter for high-resolution stereo graphics (see section B15).

Stereo imagery is an extremely convincing way of conceptualizing landforms and relative position of objects. The output option is available for all discrete-point boundary features (sections B2, B3, B4), DTM boundary features (section B5), and distorted-square terrain depictions (section B9).

ALTER BOUNDARY

This output option is only available when digitizing a boundary-type, discrete-point feature. See section B13. The option is not offered until after the first time a feature is viewed from a specific viewpoint. The idea here is that the user should see a perspective simulation before deciding to alter the activity boundary. This omission may be overridden by pressing [k6] CHOOSE OPTIONS again, which fools the computer into believing it is the second time through the Program Branching Options choice.

CHANGE VIEWPOINT

This option starts the viewpoint selection procedure over at the beginning (see section B7). The option is available for

all perspective-output sections of the program. The option is not offered until after the first time a feature is viewed from the previous viewpoint, as discussed under the ALTER BOUNDARY option.

TREE GROWTH INCREMENT

This option is offered with all boundary-type feature output sections of the program (sections B2, B3, B4 and B5). The option, offered after the first time a feature is viewed from a specific viewpoint, allows an alteration in tree height -- either increase or decrease. See section B12 for a complete discussion.

CHANGE VIEW DIRECTION, WIDTH-OF-FIELD

This option, offered after the first time any perspective output is generated from a specific viewpoint, allows the user to redirect the view line-of-sight and/or reselect the width-of-field. See section B8 for a full explanation of how this is done.

PRODUCE NEW BOUNDARY BY DIGITIZER
PRODUCE NEW BOUNDARY BY TRAVERSE
RETRIEVE BOUNDARY FROM DISK STORAGE
NEW DIGITAL TERRAIN MODEL
CC, PC, GROUND OR TERRAIN FROM CURRENT DTM

These options are offered in <u>every</u> section of the program. They allow the user to start over at the beginning of <u>any</u> feature portrayal process. The options are documented in sections B2, B3, B4, B5 and B20.

TRACK ELEVATION FROM DTM
OBTAIN SKYLINE PROFILES FROM DTM
DRAW ROAD PROFILES FROM DTM
ELEVATION ZONES
OVERLAND FLOW PATTERN
SLOPE OR ASPECT ZONES
COMBINED SLOPE/ASPECT/ELEVATION ZONES

All of these options are offered when examining terrain attributes of a Digital Terrain Model. Full description is contained in section B21.

14. Choose Program Branching Option

1. CRT will offer choice of branching options at appropriate times.
2. To abort program and reroute to the branching options choice, press PAUSE k6 CHOOSE OPTIONS
3. If full list of options is not offered, press k6 again.
4. Enter number of desired option CONT

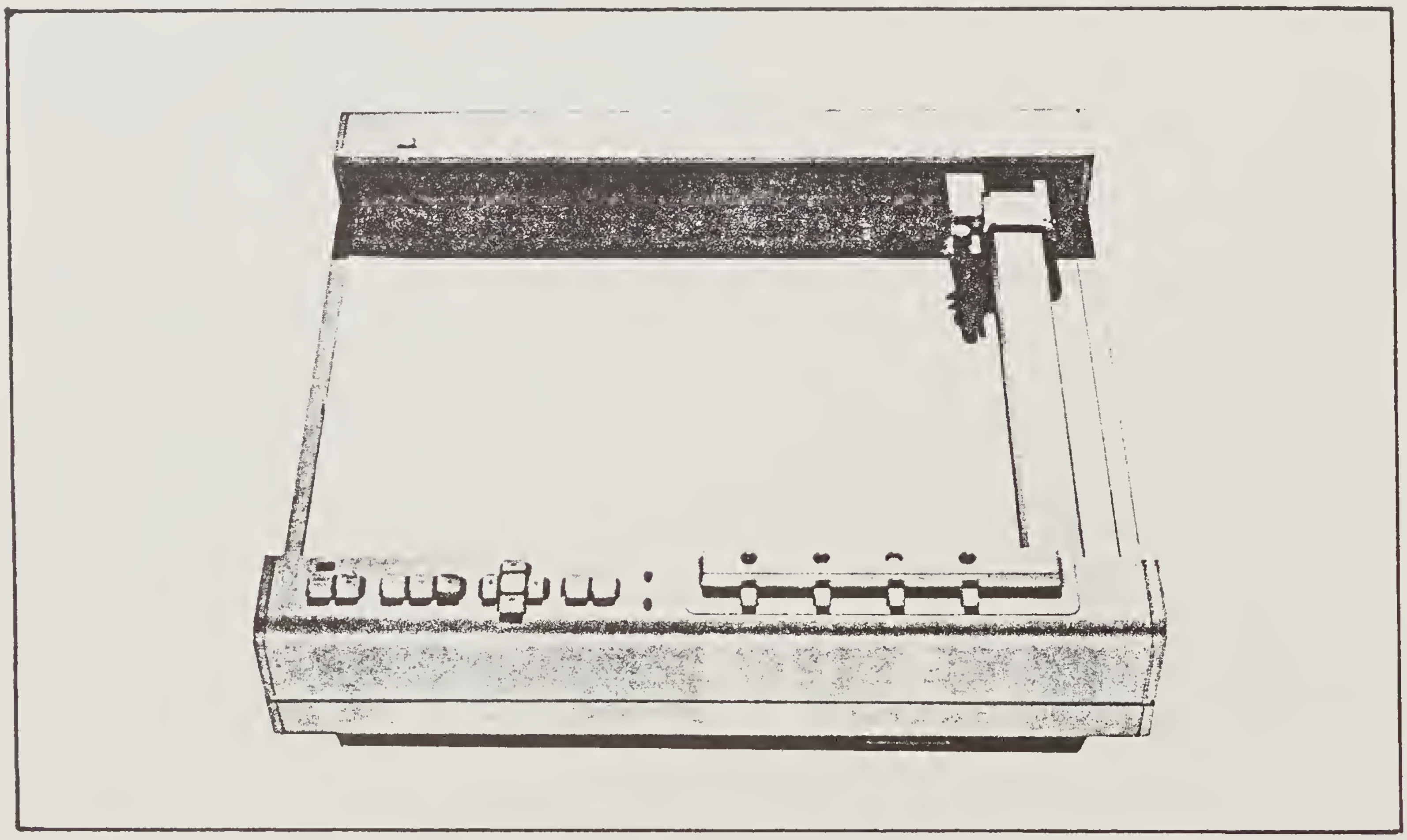


Figure B15-1. The HP9872A Four-color Flat-bed Plotter.

15. Flat-Bed Plotter Outputs

All graphical presentations appear on the CRT by default. Plotting on the CRT is quite rapid, and the image is temporary. This is an aid to interactive operation, resulting in a reduction in the scrap paper that might otherwise be generated by a PERSPECTIVE PLOT work session. However, when the design work is done, a high-quality presentation graphic of the final product may be desired. The 10" x 15" flat-bed plotter will produce a four-color, high-resolution plot that is far superior to CRT graphics dumps.

Flat-bed plotter graphics may be obtained of single PERSPECTIVE PLOT views or stereo PERSPECTIVE PLOT pairs ONLY! All other graphics (view direction and width-of-field graphic, seen-area overlay, DTM graphic, etc.) are portrayed only on the CRT. Invoke the flat-bed plotter just prior to selecting one of the perspective outputs from the options menu. Or, interrupt CRT execution of one of these options, if it is apparent that the image is satisfactory, by pressing [PAUSE]. Then invoke the flat-bed plotter.

The flat-bed plotter is invoked by pressing Special-Function Key [k14] FLATBED PLOTTER. A block of instructions appears on the CRT describing the correct color arrangement of the pens.

NOTE: IT IS EXTREMELY IMPORTANT THAT THE PLOTTER BE SWITCHED "ON" PRIOR TO PRESSING [k14] -- FAILURE TO DO SO WILL CAUSE A "DEVICE TIMEOUT" -- A FATAL PROGRAM ERROR FROM WHICH IT IS DIFFICULT TO RECOVER! THE COMPUTER ATTEMPTS TO CONVEY COMMANDS TO A PERIPHERAL DEVICE THAT IS NOT POWERED UP.

Press the [CHART LOAD] key on the plotter, to move the pen out of the way. Install the paper and press [CHART HOLD]. Smooth the paper onto the plotter surface; it is electrostatically held in place. Use the plotter up, down, left, and right arrow keys to locate the lower left corner of the plotting area (be sure this is somewhere on the sheet of paper!). When this is found, press the plotter [ENTER] key -- yellow key with a light in the center. Repeat this procedure for the upper right corner. Note that the plotting area can be any size or shape, up to the limits of the plotter surface. The aspect ratio of the plotting area may be different from that of the CRT, allowing more horizontal or vertical extent of a feature to be shown. Returning to the PERSPECTIVE PLOT analogy, the flat-bed plotter can be thought of as an enlarger. The size of the "print" depends on how big a piece of photographic paper is available -- wallet-size to portrait blow-up. The "view distance" figure in the upper right corner may be different from CRT plots, reflecting the degree of reduction or enlargement.

The Options Menu appears after sizing the plotting area. Choose the appropriate output (see section B14).

For stereo plots, change the paper after the first output (RIGHT EYE) is done. Then press [CONT] and the second output (LEFT EYE) is plotted. For single PERSPECTIVE PLOT outputs,

press $\boxed{\text{CHART LOAD}}$ and remove the plot. Then press $\boxed{\text{CONT}}$. Plotting reverts to the CRT for subsequent graphical outputs.

If the paper is not removed from the plotter, subsequent plots may be repeated, in the manner of the sequential transparency overlays in many of the Case Studies. When reinvoking the plotter, just press $\boxed{\text{ENTER}}$ twice -- do not move the plotting limits.

Transparencies can be plotted directly on clear acetate. Special pens are required, which can be obtained from the manufacturer. The acetate ink takes about ten minutes to dry, so carefully remove the transparency and set it aside so it does not get smeared.

15. Flat-Bed Plotter Outputs

1. Invoke flat-bed plotter for single or stereo PERSPECTIVE PLOTs.
2. Set limits with plotter arrow keys and $\boxed{\text{ENTER}}$
3. Choose output option.
4. Press $\boxed{\text{CHART LOAD}}$ to move pen aside.
5. Press $\boxed{\text{ENTER}}$ followed by empty pen-stable key to return a pen to the pen stable (this prevents the pen from drying out between plots).

```
LIST OF CURRENT STORAGE FILE CONTENTS:
 1 Traversed Clearcuts
 2 UPPER EAST FORK CC's
 3 UNITS 1-5, RIDGES -- COPPERHEAD (HOOD RIV R.D. 12/14/79)
 4 DUPLEXES
 5 NORTHRIDGE CC HARVEST
 6 PILOT KNOB (10/24/79,CDH)
```

Figure B16-1. A catalog of stored Feature Boundary titles.

16. Storage of Feature Data

An opportunity is presented to store activity features built by the following methods:

Discrete-point -- Digitizer (section B2)
Discrete-point -- Traverse Data (section B3)
Feature from Digital Terrain Model (section B5)

Stored features can be retrieved for further examination (see section B4). The data on the set of points comprising the feature's boundary is stored -- coordinates, elevation, crown size, crown shape. Consequently, the feature is recalled as a discrete-point feature, even if originally obtained from a Digital Terrain Model.

When asked:

WANT TO STORE FEATURE BOUNDARY INFORMATION(Y or N)?

respond appropriately. A numbered list of six currently-stored feature titles appears (see figure B16-1). The computer asks:

STORE INFORMATION IN WHICH FILE (1-6 0=don't store)?

Select a storage file. Prior contents are lost when a storage file is reused. A zero input provides an opportunity for a last-minute change of mind.

The computer will display:

FEATURE IDENTIFICATION - UP TO 60 CHARACTERS stops here-->|

Type in the name of the feature, plus any other pertinent information up to 60 characters (e.g. date, user name, "SAVE"). The feature information is then stored on the program disk, and program execution continues.

16. Storage of Feature Data
1. Respond Y [CONT] to query to store feature.
2. Select a file, 1 to 6 [CONT]
3. Enter feature name and identification -- up to 60 characters [CONT]
4. Feature data is stored as discrete-point data.

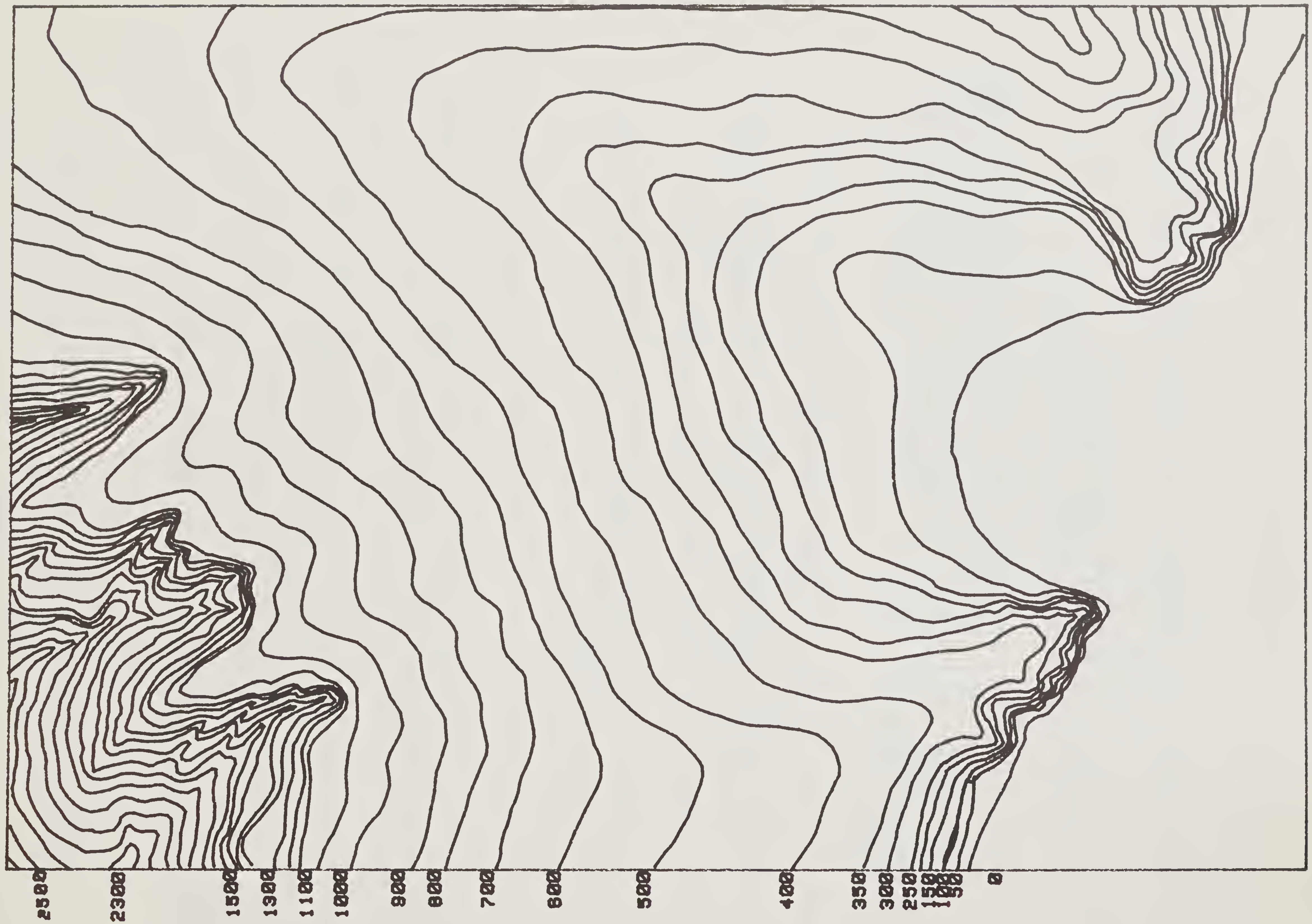


Figure B17-1. An example map base for building a Digital Terrain Model (DTM). This terrain is the area shown in Case Study 9.

17. Constructing a Digital Terrain Model

Section B5 covers the describing of a proposed feature using a Digital Terrain Model. Refer to that section for a discussion of Digital Terrain Models.

The PERSPECTIVE PLOT Digital Terrain Model (DTM) is built by passing the digitizer cursor along the contour lines of a topographic map. Since this is an easily-mastered technique, building a DTM is not difficult. Nevertheless, there is some "art" involved, and DTMs will look better with a little practice. Some basics to observe:

* Choose a clear map base, uncluttered with detail and showing easily-followed contours.
* Choose as large-scale a map as will fit inside the digitizer surface (12" x 17"). Larger sizes, though possible to work from, are somewhat inconvenient and do not achieve very much addition to detail.
* Plan a sequence of digitizing. No particular order of contours need be followed, but it makes sense to proceed in some systematic way.
* Make sure the elevation of each contour line is easily determined. Write the elevations in, if necessary.

Draw a rectangle in cardinal directions (north-south, east-west) around the piece of terrain to be modelled. There is no limit on the acreage that can be modelled, but the resolution of the model varies with the acreage portrayed. Models from 20 acres to 20000 acres have been used successfully in projects to date. Larger acreages will serve for longer-distance perspective depictions.

Clearly mark the southwest and southeast corners of the rectangle. These points will serve to orient the map base. Mount the map base on the digitizer. Use masking tape to hold the map firmly in place. Figure B17-1 shows an example map base.

Building a DTM will have commenced when the user responded N [CONT] to the question (in section B5):

WANT TO RETRIEVE A DTM YOU HAVE PREVIOUSLY STORED(Y or N)?

The CRT will display the question:

Map Scale (ft per inch)?

Type this figure in followed by [CONT] . Note that the proper response for a 4"=1 mile map is 1320, since this scale equals 1320 feet per inch, and the proper response for a 1:12000 map is 1000, since this scale equals 1000 feet per inch.

Next, orient the map to the digitizer as directed by the CRT display. Digitize the southwest corner, then the southeast corner. Press [CONT] when this is done. Next, digitize the northeast corner of the rectangle, as instructed on the CRT. Either the north-south or the east-west dimension of the enclosing rectangle will determine the scale of the DTM. Since

the computer CRT has space available with an aspect ratio of 13:16, this is the available aspect ratio for a model. Extra space -- beyond the enclosing rectangle on the map base -- is usually available either to the east or to the north. Following digitizing the northeast corner, all work will be at the digitizer work station. A "CHARGE" signal sounds from the digitizer to warn that DTM input has begun.

The digitizer display will read:

| EL of COntOUr? |

Type in the elevation of the first contour to be digitized, using the digitizer number key pad. Use CLEAR if an error is made. Press ENTER to store the number. The cursor is automatically set to Continuous mode. Press the D key on the cursor, and start moving down the contour line, moving fairly slowly. The sampling rate may be judged by the speed with which the light on the cursor flashes. The CRT will reproduce the contour being digitized, along with an occasional "+" symbol. These "+" symbols are the grid points at which elevations are retained, constituting the Digital Terrain Model. They will eventually join together to form an unbroken grid.

When a contour is completed, press the D key to stop sampling. fe NEW CONTOUR will branch back to the contour-elevation input. Digitize all contours in this manner. Note that separate segments of the same elevation contour must be treated as NEW CONTOURs, or a confusing line will be drawn from the endpoint of one segment to the beginning of the next.

It may only be necessary to digitize every other or every third contour, if the topography is sufficiently steep. On the other hand, it may be necessary to "interpolate" contour locations on flat terrain. Let the density of the "+" symbols be the guide.

If an error is made while digitizing, there may be a way to correct it, short of starting over. If the user reaches the end of a contour, only to notice that he has typed in an incorrect elevation (displayed on the digitizer), he may <u>change</u> the elevation to the correct one. <u>All grid points assigned the incorrect elevation are changed, including points</u> on contours of the same elevation other that the one just completed. Another common mistake is that digitizing may have wandered onto the wrong contour line, or down a property line or roadway feature on the map. The user may <u>delete</u> such contours. <u>All grid points assigned the incorrect elevation are deleted, including</u> points on contours of the same elevation other than the one just completed.

Initiate corrections by pressing fb ERROR CORRECT. The digitizer display will read:

ERROR CORRECt
CHANGE ELEU=1
DELEtE ELEU=2
CH=1 DEL=2

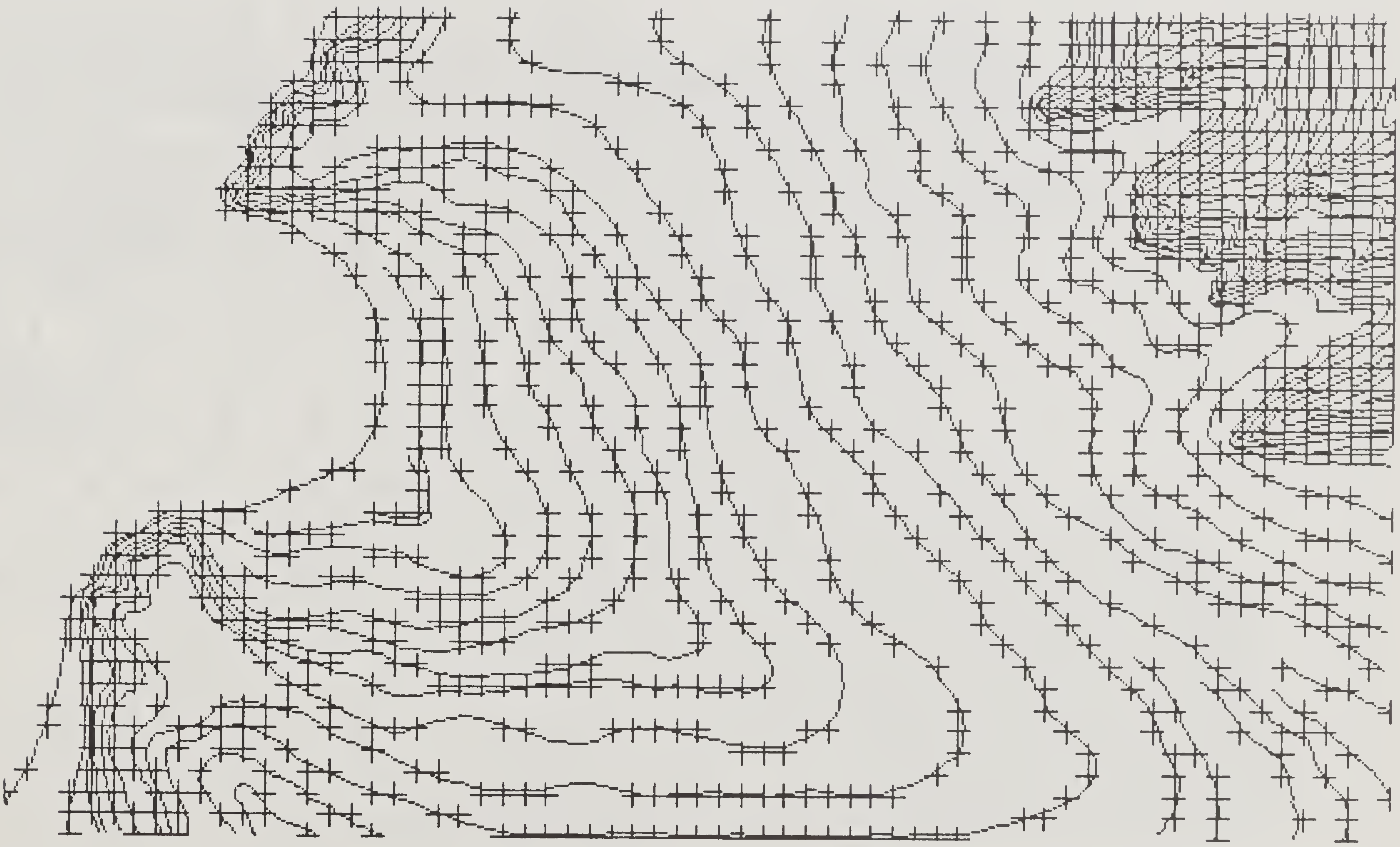


Figure B17-2. Digitizing the contours has been completed. Numerous gaps exist in the DTM, and should be filled in by one of the available methods.

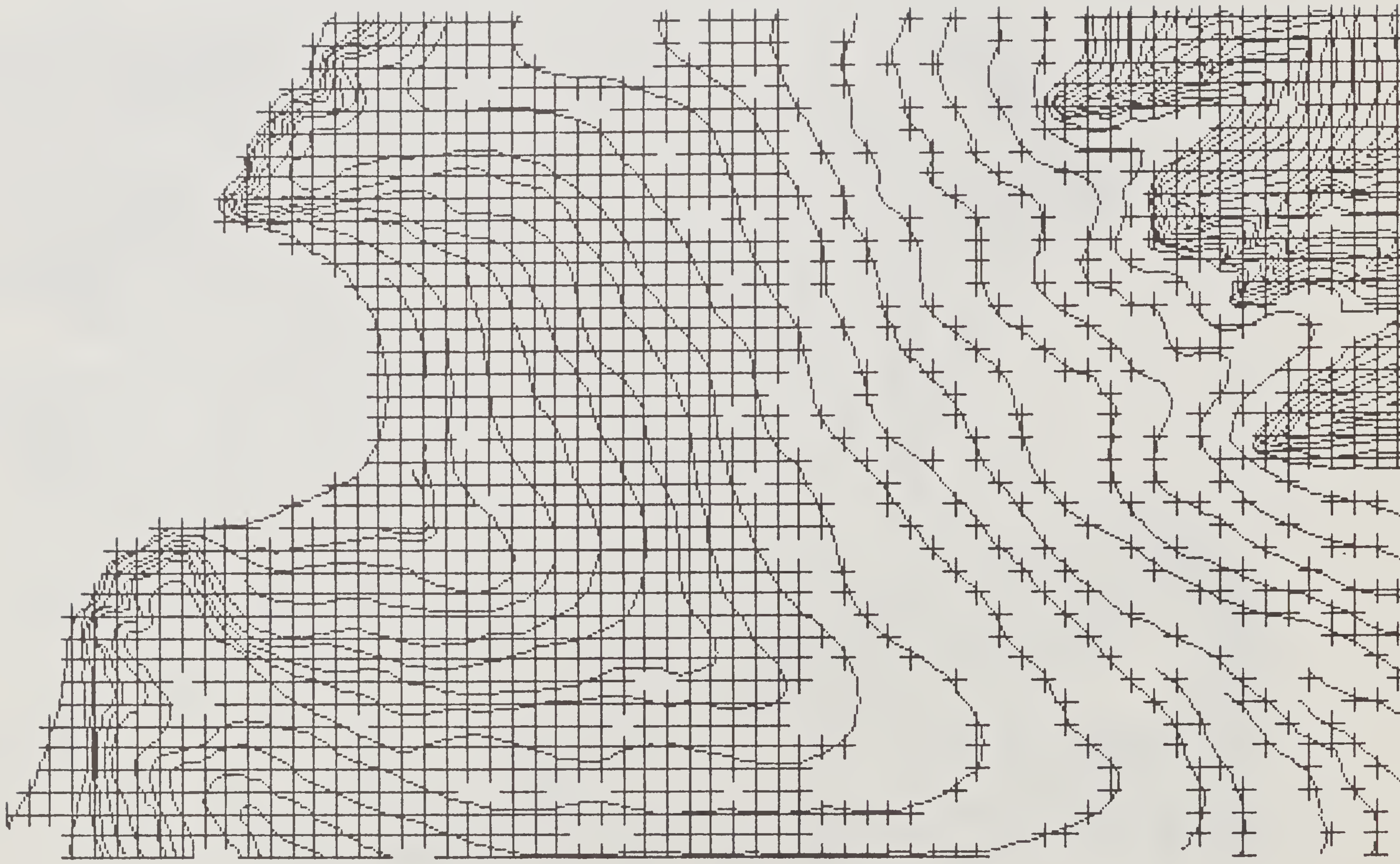


Figure B17-3. Fill-in of missing points by interpolation has progressed about half-way from left to right.

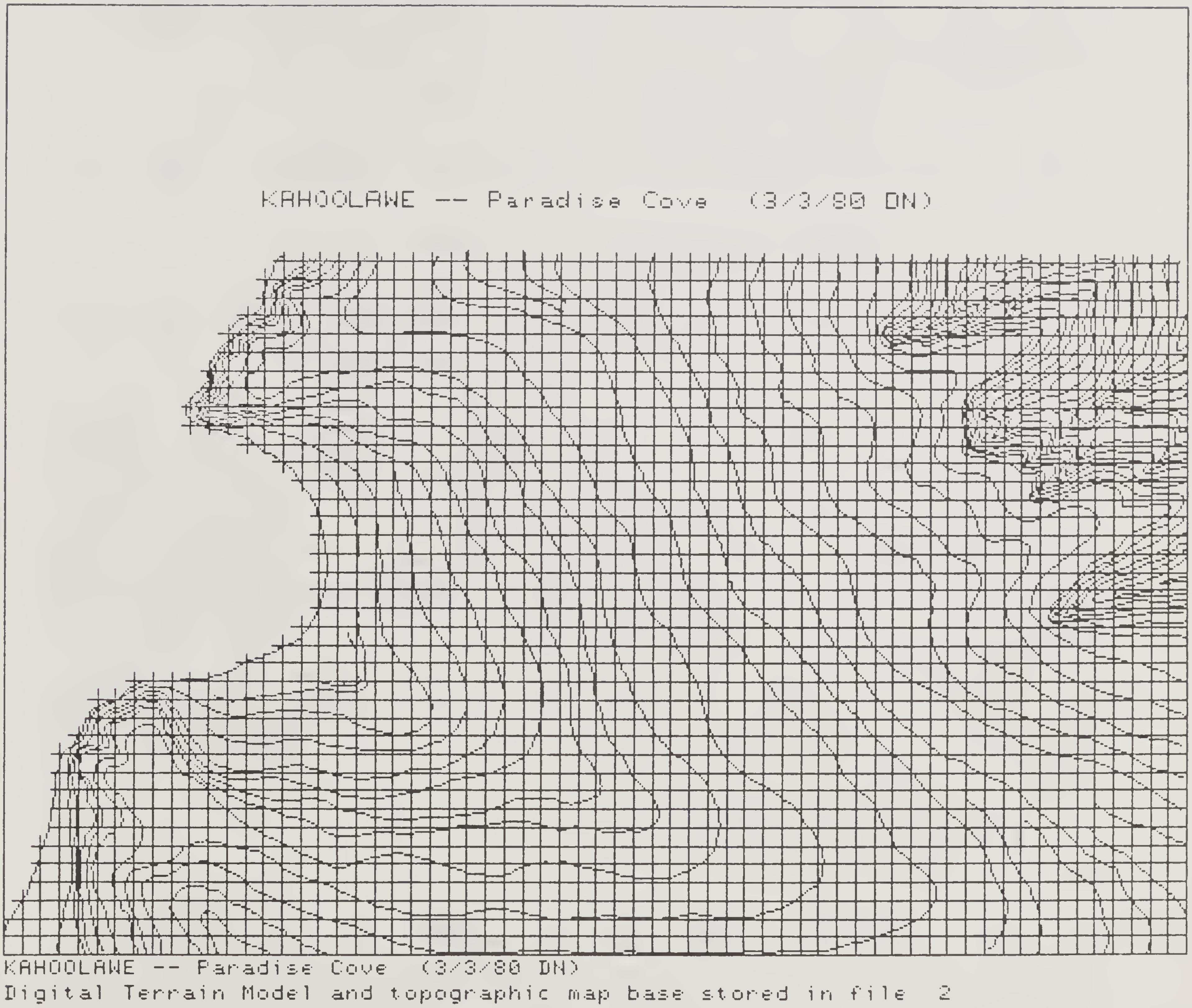


Figure B17-4. The Digital Terrain Model has been completed. Grid points in the upper area are not shown, since the model was not extended to occupy all the available area.

Type in the appropriate code using the digitizer number keys, followed by ENTER. If CHANGE, the display will read:

ELEU to CHANGE?

Type the erroneous elevation in, followed by ENTER. Then the display will read:

CORRECt ELEU?

Type the correct elevation in. followed by ENTER. If DELETE, the display will read:

ELEU to DELETE?

Type the erroneous elevation in, followed by ENTER.

As the computer corrects errors, the CRT will display a small flashing "+" crosshair moving rapidly across the DTM. When the crosshair encounters a grid point that is in error, a small explosion occurs on the CRT (Do not worry about flying glass -- it's a visual effect only!) Deleted grid points disappear, and changed grid points are corrected internally. Note that no change occurs to the plotted contour line -- it is left in the graphic. But the DTM consists of the grid points, not the contour lines. Pressing [ ] fe NEW CONTOUR will allow replacement of deleted contour data, or continuation of model building. The display reads PrESS FSE or FA as a prompt to continued digitizing or finishing. [ ] fb may also be keyed to repeat error corrections.

When the user has digitized as many contours as he wants, he presses the fa FINISHED key. Figure B17-2 shows a DTM just prior to this step. Gaps that remain after finishing digitizing may be closed by three methods:

1. Filling-in gaps by interpolation F
2. Digitizing more contours D

or 3. Locating specific points L

The CRT displays these choices. Type in the appropriate letter, F, D, or L, followed by CONT. The letter C (for Continue with the program) indicates that the DTM is in final condition.

The fill-in routine can bridge small gaps in the model by a bi-directional linear interpolation. The CRT displays a full-screen crosshair, moving rapidly across the DTM. When the crosshair encounters a blank grid point, it pauses an instant while the computer figures an interpolated elevation. Note that it is not possible to bridge large gaps by interpolation, but "bridging" points may be selected by Locating specific points. Figure B17-3 shows a DTM after interpolated fill-in has progressed about half-way across the DTM shown in figure B17-2.

Repeating the fill-in routine forces the computer to re-interpolate, closing up the smaller gaps. This proceeds very quickly, but may tend to result in smoother-than-life landforms.

Digitizing new contours affords the opportunity to go back and pick up areas that were lightly treated or missed entirely in digitizing. It may be necessary to infer contour locations between map contours for gentle terrain. [ ] [fe] NEW CONTOUR may be repeated until [fa] FINISHED is pressed, just as before.

Locating specific points allows the input of samples that may bridge larger gaps, prior to going through the interpolated fill-in. As the CRT instructions indicate, press [CONT] to start, then press the [D] key on the cursor. The full-screen CRT crosshair moves to show the digitizer cursor's location. Move the crosshair to center on a missing grid point. Then press [fa] FINISHED. The digitizer display reads:

[ELEU OF POINt?]

Read the elevation at the cursor and type this figure in on the digitizer keypad, followed by [ENTER]. The display then reads:

[1=AGAIN 0=DoNE]

Type in the appropriate code, followed by [ENTER]. The user is allowed either to repeat the location of specific points, or escape to the DTM-completion options.

Figure B17-4 shows the completed DTM, with all internal gaps filled in. The thermal-printer copy is automatically produced, and of course can be repeated by pressing [k5] DUMP GRAPHICS. A statistical summary of the DTM digitizing procedure is performed and the end-result -- a confidence interval -- is printed. This is based on a t-statistic, comparing the absolute elevations of up to 50 sample points with the calculated elevations obtained from the DTM. The interval suggests that 90 percent of the elevations determined from the DTM will be within so many feet of correct, based on the map as digitized. No inference as to accuracy of the original map or accuracy of the digitizing is made. A confidence band on the order of 1/4 contour interval can be regarded as typical.

The CRT asks:

Want to store this Digital Terrain Model (Y or N)?

A Y response branches to DTM storage (section B18). A N response branches directly to the DTM options choice, discussed in section B20.

17. Constructing a Digital Terrain Model

1. Mount map base on digitizer, with rectangle drawn around area of concern.
2. Input map scale, feet per inch [CONT]
3. Align map by digitizing SW and SE corner. Then press [CONT]
4. Set scale of DTM by digitizing NE corner.
5. Input elevation of a contour, using digitizer keys and [ENTER]
6. Digitize contour slowly. Contour and grid points are plotted on CRT.
7. Press [ ] [fe] for new contour line (go back to step 5).

17. Constructing a Digital Terrain Model (cont)

8. Press $\boxed{}$ $\boxed{fb}$ to correct errors.
9. Press $\boxed{fa}$ when entirely finished.
10. Choose any of three techniques to complete gaps in the model.
11. When ready to continue, statistical accuracy of DTM is printed, followed by thermal-printer copy.

```
        CURRENTLY STORED DIGITAL TERRAIN MODELS:

 1 MONTANA -- Coyote Basin Reservoir  (3/12/80 DN)
 2 KAHOOLAWE -- Paradise Cove  (3/3/80 DN)
 3 Unsightly Borrow Pit AFTER DEVELOPMENT
 4 Mt.Solo, Longview, Washington (IP Co.) (DBN 5/1/80)
 5 UPPER LITTLE KACHESS LAKE 10/1/79
 6 Bachelor Butte, Deschutes N.F. (4/16/80 DN)
```

Figure B18-1. A catalog of stored Digital Terrain Model titles.

18. Storing a Digital Terrain Model

Terrain that has been described by building a Digital Terrain Model (see section B17) can be permanently stored on a disk. Both the numerical model and the CRT graphic are stored. The user need only digitize sensitive terrain once, thenceforth having it permanently available for visual, terrain, or engineering analyses.

Up to six DTMs are stored on a single disk. One data file is a "table of contents," holding the 60-character description of each DTM. Six pairs of data files hold the numerical models and CRT graphics for the six DTMs.

If it is necessary to create a new DTM DATA disk, this may be easily done. But creation of a new disk must be performed ahead of time -- the user cannot interrupt the PERSPECTIVE PLOT program to create a new DTM DATA disk without losing the DTM he has built. To create a new DTM DATA disk, load the program SETUP, which is found on the PERSPECTIVE PLOT PROGRAM disk:

```
LOAD"SETUP:F8"  [EXECUTE]
[RUN]
```

Follow the simple instructions to set up an initialized blank disk to receive DTM data.

Storing a DTM must be performed immediately after constructing the DTM. If the opportunity to store the model is declined, the user may work with the model but will lose the terrain data upon shutting down the computer.

The user is asked to:

```
INSERT DATA DISK IN FLEXIBLE DISK DRIVE--then press [CONT]
```

If several DTM DATA disks are available, they must be identified or numbered so that the proper disk may be selected. Upon pressing [CONT] the table of contents is accessed and displayed (figure B18-1). At this point, if the wrong DTM DATA disk has been inadvertently used, simply press [STOP] and then [RUN]. The sequence starts over again, and another DTM DATA disk can be tried.

Select the storage location to be used by typing in its number, in response to the prompt:

```
Store DTM in which file (1 to 6    0=Don't Store)?
```

An input of 0 enables bypassing the storage procedure. Other numbers must be 1 through 6. Otherwise, a printout of available storage positions is listed and another chance to store the DTM is offered. Press [CONT]. The display asks:

```
Name/Description of DTM (under 60 characters    stops here->|
```

Type in the name and descriptive information about the DTM (e.g. author, date, "SAVE") and press [CONT]. If space allows, the DTM identification is labelled on the graphic. The DTM

data and graphic are stored on the disc (requiring about 20 seconds) and a hard copy of the DTM is printed. The computer verifies that the DTM has been stored. The CRT displays:

REPLACE PROGRAM DISK IN FLEXIBLE DISK DRIVE--then press [CONT]

Upon doing this, the program moves on to choosing the output desired from the Digital Terrain Model (see section B20).

18. Storing a Digital Terrain Model

1. Insert DTM DATA disk [CONT]
2. Select storage file [CONT]
3. Type in DTM name/description [CONT]
4. DTM is stored; copy is printed
5. Reinstall PERSPECTIVE PLOT PROGRAM disk.

19. Retrieving a Digital Terrain Model

Digital Terrain Models can be stored permanently on a DTM DATA disk (see section B18). The capturing of a numerical description of highly sensitive blocks of terrain is one of the chief attractions of the DTM approach.

Upon branching to the DTM retrieval procedure (refer to section B5 to see how this is accomplished), the CRT displays:

INSTALL DTM DATA DISK IN DISK DRIVE UNIT--then press [CONT]

Remove the PROGRAM disk and install a DTM DATA disk. The CRT displays a numbered list of the DTMs stored on the DTM DATA disk (see figure B18-1).

If the wrong disk has been installed, press [STOP] then [RUN]. The sequence begins again, and another disk can be tried.

The CRT asks:

RECALL DTM FROM WHICH FILE (1 -- 6)?

Type in the desired number. In about five seconds the computer retrieves and displays the DTM graphic image. In about ten more seconds, the computer retrieves the numerical information that constitutes the model. A graphics dump occurs, and the CRT displays:

REPLACE PROGRAM DISK IN DISK DRIVE--then press [CONT]

Upon doing this, the program branches to the DTM output choice (section B20), carrying the DTM information in memory.

19. Retrieving a Digital Terrain Model

1. Install DTM disk [CONT]
2. Press [STOP] [RUN] to start over.
3. Select desired number from list of DTMs.
4. CRT produces DTM graphic image.
5. Graphics dump produces thermal-printer replica of DTM.
6. Replace PROGRAM disk [CONT].
7. Program branches to DTM output choice.

20. Choose Digital Terrain Model Output

The PERSPECTIVE PLOT program offers a choice of four output options, once the user has constructed or recalled a DTM. The four choices are:

1. Clearcut timber harvest boundaries, or other forest openings. See Case Study 1, 3, and 5 for examples. The procedure for this option is discussed in section B5.
2. Partial-cut timber harvest activities, or surface and vegetation textures. See Case Study 1, 6, 8, and 9 for examples. The procedure for this option is discussed in sections B10 and B11.
3. Distorted-square terrain depiction plus seen-area graphic. See figure B9-1 and Case Study 1, 3, and 5 through 9 for examples. The procedure for this option is discussed in section B9.
4. Terrain features: slope, aspect, and elevation zones, skyline payload analysis profiles, road location profiles, and overland drainage patterns. See Case Study 4 for examples. The procedure for this option is discussed in section B21.

Select the output wanted, and type in its number, followed by [CONT]. The program branches to the indicated section.

20. Choose Digital Terrain Model Output
1. CRT displays four DTM output choices.
2. Type in desired choice number [CONT]
3. Program branches to indicated section.

21. Analysis of Terrain Attributes

The Digital Terrain Model presents a valuable opportunity to exploit the terrain information that has been captured. Sections B5, B9, B10, and B11 examine visual simulation outputs obtained from DTM terrain information. This section examines other kinds of outputs. There are seven terrain attribute options, each of which will be discussed separately.

TRACK ELEVATION FROM DTM

This option simply allows the user to get elevation information back from any point on a Digital Terrain Model. Affix the thermal-printer replica of the DTM map base (not the original map base!) to the digitizer, and align the map by digitizing the southwest and southeast corners. The CRT displays instructions to assist in this task. When finished, press CONT. Next, the computer pauses a moment to find the lowest and highest elevations in the DTM. The CRT clears and displays an elevation scale, or "altimeter." When the display shows BEGIN DIGITIZING, press the D key and move the cursor about on the DTM. The CRT crosshair fixes on the elevation and the digitizer tone beeps with a pitch proportional to the elevation.

Use this option to verify the quality of the DTM. Run the digitizer along one of the contours. There should be very little fluctuation in elevation, depending on how much care and skill was employed when building the DTM. The digitizer tone provides audio feedback, so the user (if not tone-deaf!) may not find it necessary to look at the CRT at all!

The CRT crosshair vanishes and the tone falls silent when the digitizer cursor is taken outside the DTM.

Sensitive individuals within earshot of the digitizer may find their concentration disturbed by the digitizer tone. To avoid bodily injury, the user may find it adviseable to lower the volume. The volume control is a knob on the back of the digitizer, toward the left side.

Press fa FINISHED on the digitizer Special-Function Keys to terminate this operation.

OBTAIN SKYLINE PROFILE FROM DTM

The user can obtain ground profiles for analyzing skyline logging system payloads. These profiles are a series of elevations along a straight line between two endpoints. Skyline profiles are described in format to be analyzed by the HP9845 program LOGGER, which was written and documented (in a companion publication to this one) by the author of PERSPECTIVE PLOT. Moreover, the skyline profile data is stored on the LOGGER program disk, where they can await payload analysis at the user's convenience.

On selection of this option, the CRT displays

INSERT SKYLINE DATA DISK FOR PROFILE STORAGE--then press CONT

Remove the PERSPECTIVE PLOT PROGRAM disk and install the LOGGER PROGRAM disk. Then press CONT. The CRT displays a catalog

of available profile storage files, similar to this:

NAME	PRO	TYPE	REC/FILE	BYTES/REC	ADDRESS
F8	65				
P--SO		DATA	100	400	2/15
P--BVY		DATA	100	400	7/20
P--BNS		DATA	100	400	12/25
P--LCK		DATA	100	400	17/30
P--PCY		DATA	100	400	22/35

Then the CRT asks:

FILE IN WHICH PROFILES ARE TO BE STORED (up to THREE letters)?

Enter the file ID code -- the two or three letters following "P--". For example, the response identifying the first file on the above list is SO [CONT].

The CRT then prompts:

DIGITIZE END OF PROFILE NEAREST HEADSPAR

Do this, using the cursor's [D] key. The CRT prompts:

DIGITIZE END OF PROFILE NEAREST TAILHOLD

Again use the cursor's [D] key. The CRT asks:

PROFILE NAME OR IDENTIFICATION (UP TO 8 CHARACTERS)?

After entering the profile name, the CRT produces a plot of the profile. Terrain points are spaced the same distance apart as the Digital Terrain Model grid spacing, except that no profile will exceed 50 terrain points. Long profiles, consequently, have a terrain point spacing equal to 1/49th of the profile length.

No portion of a profile can be outside the DTM. If the computer senses this to occur, it tells the user and offers another chance to digitize a profile's endpoints.

Press [k5] DUMP GRAPHICS if a hard copy of the skyline profile is desired (see figure C1-4). The CRT displays a numbered list of 100 profile storage slots -- some possibly occupied by an eight-character profile name. The CRT asks:

STORE PROFILE IN FILE NO ______?

Enter a number, 1 through 100, and the profile coordinates will be stored on the <u>LOGGER</u> program disk. The CRT then asks:

WANT TO OBTAIN ANOTHER PROFILE (Y or N)?

The user may continue to generate and store profiles by answering Y [CONT]. The process is terminated with a N [CONT]

response, and the CRT prompts:

REPLACE PRSPLOT PROGRAM DISK--then press $\boxed{\text{CONT}}$

Remove the LOGGER disk and reinstall the PERSPECTIVE PLOT PROGRAM disk. Upon pressing $\boxed{\text{CONT}}$ the program returns to the branching options choice menu.

Note that skyline profiles obtained from the DTM may be less accurate than digitizing a profile directly from the topographic map base or surveying the profile in the field. The user may nonetheless perform some tentative payload investigations and narrow the focus for field-obtained profiles by judiciously using DTM-obtained skyline profiles.

DRAW ROAD PROFILES FROM DTM

Proposed road profiles may be generated, in segments of several thousand feet. Identify a road centerline on the thermal-printer replica of the DTM. This map will have been affixed to the digitizer and aligned, prior to selection of this output option. Upon selecting the Road Profiles output, the CRT is ruled in increments of 100 feet, in both the horizontal (station) and vertical (elevation) direction. The digitizer will take continuous samples as the user moves the cursor along the road centerline. The profile is drawn on the CRT. The profile automatically terminates and a graphics dump is produced when the horizontal limit is reached. The program returns to the branching options choice menu.

ELEVATION ZONES

Upon selection of this option, the user is asked:

LOWER ELEVATION LIMIT?
and
UPPER ELEVATION LIMIT?

Answer each of these questions. The computer will examine the entire DTM and produce a graphic that identifies all grid points higher than the lower limit and lower than or equal to the upper limit. The points between these limits are identified by an asterisk, in a graphic that is exactly the same scale as the thermal-printer DTM replica. The graphic takes about three minutes to be produced, and is automatically dumped on the thermal printer. See figure C4-3. The computer prints the acreage possessing this elevation attribute, and the total acreage in the Digital Terrain Model.

OVERLAND FLOW PATTERN

Upon selection of this option, the computer produces a graphic output showing, by means of arrowhead symbols, the direction of slope for all DTM grid cells over 3% slope steepness. The graphic is plotted at the same scale as the thermal-printer DTM replica, and is automatically dumped when complete. Graphic generation can take up to about ten minutes.

The computer examines the elevations of the four corners of each grid cell. A planar surface is passed through these four

points, by a least-squares method. The slope and aspect of the planar surface is analyzed, and the arrowhead symbol produced points downhill along the steepest gradient.

After completion, the program returns to the branching options choice menu.

SLOPE OR ASPECT ZONES

If this option is selected, it will have been necessary for the OVERLAND FLOW PATTERN option to have been previously performed. If it has not, the computer first goes through that routine, then returns to the SLOPE OR ASPECT ZONES option.

After displaying instructions, the CRT asks:

Do you want to show SLOPE or ASPECT (S or A)?

Answer as appropriate. If slope, the CRT asks:

LOWER SLOPE LIMIT (Percent)?
and
UPPER SLOPE LIMIT (Percent)?

Answer each of these questions. If aspect was chosen instead, the CRT asks:

ASPECT AZIMUTH FROM _____, TO _____ (0 to 360, both inputs)

Answer by typing in both aspect limits, separated by a comma. Note that the limits are always entered in a clockwise direction. For example:

this input...	identifies this range
40,90 CONT	from 40 to 90 (50-degree range)
90,40 CONT	from 90 to 40 (310-degree range)
315,45 CONT	from 315 to 45 (90-degree range)
45,315 CONT	from 45 to 315 (270-degree range)

The CRT produces a graphic identifying the terrain lying within the indicated limits of slope or aspect. The graphic takes about three minutes to be produced, and is plotted at the same scale as the thermal-printer DTM replica. On completion, a graphics dump is automatically performed. The computer prints the acreage possessing the indicated attribute and the total acreage in the Digital Terrain Model. For aspect outputs, a North-arrow is printed, reminding the user that the computer is dealing with apparent north; the computer must rely on the user to have oriented the map properly when the DTM was produced.

COMBINED SLOPE/ASPECT/ELEVATION ZONES

The computer asks for lower and upper bounds on all three terrain attributes. Review those paragraphs for further explanation.

The CRT produces a graphic showing all terrain in the DTM possessing attributes simultaneously within all three limits. It should be apparent that management decisions in the areas of silviculture, fire control, hydrology, wildlife management,

recreation, landscape architecture, logging systems, and biology can be derived from a judiciously-chosen set of limits.

See Case Study 4 for examples of terrain attribute overlays used to make management inferences.

21. Analysis of Terrain Attributes
1. Affix thermal-printer DTM replica to digitizer.
2. Align the DTM in accordance with instructions.
3. Select option from numbered list.
4. Refer to detailed description above, for each option.

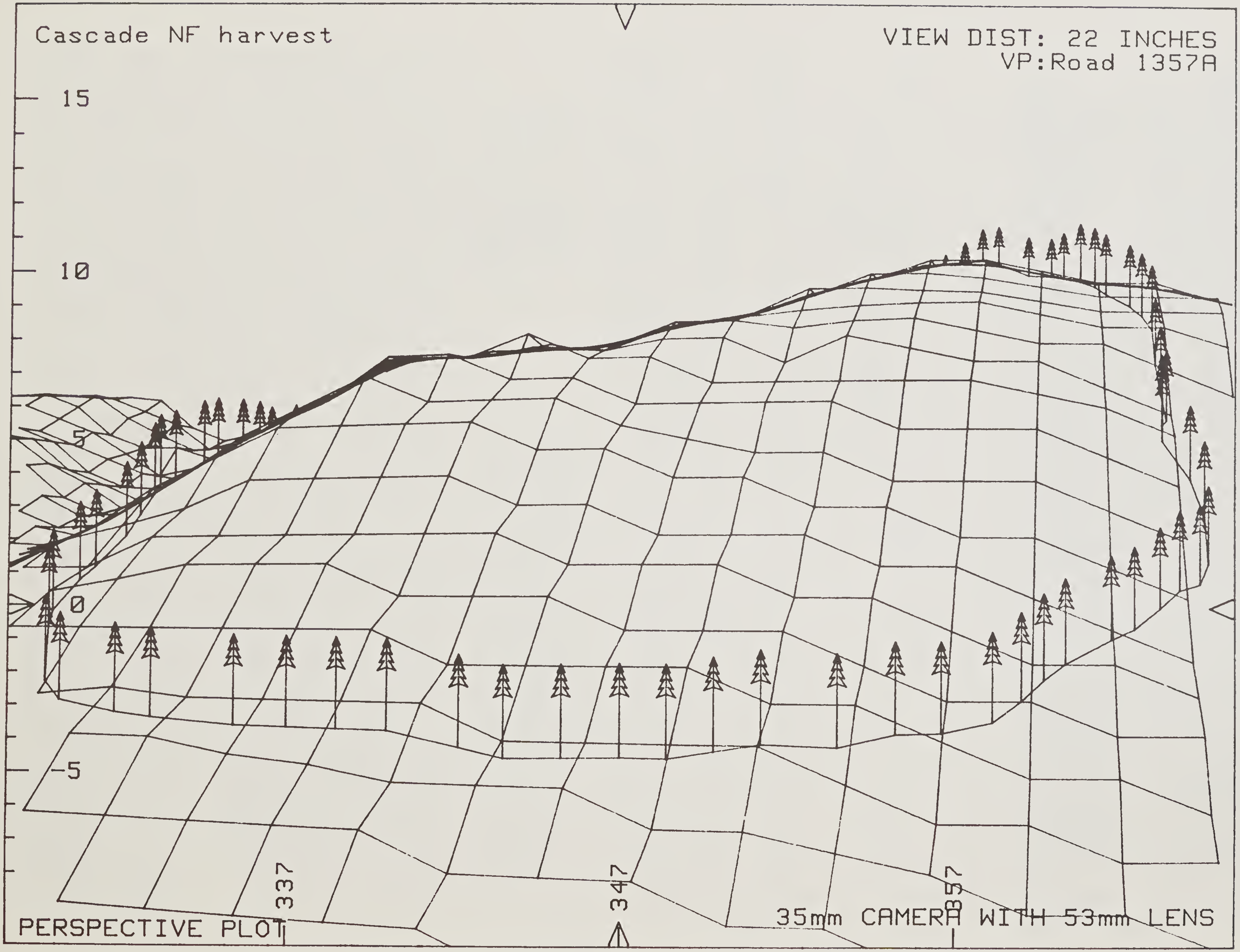


Figure C1-1. A clearcut timber harvest activity extending over the top of a ridge.

CASE STUDY 1: Timber Harvest Alternatives
Cascade National Forest, Oregon

Field reconnaissance and area harvest planning on the Cascade National Forest has identified a possible landing site for skyline cable yarding. Based on the maximum reach of available cable logging equipment. together with timber stand information and topographic breaks, a logical setting boundary has been delineated. As part of the Environmental Analysis process, timber harvest planners want to assess the visual impact of various harvest alternatives.

A PERSPECTIVE PLOT representation of the underlying terrain was obtained first, after producing a Digital Terrain Model of the area. The harvest activity lies on the near face of the foreground ridge, and extends over the top and down the far side. Over the terrain model, a final-removal boundary, representing clearcut harvesting of the entire setting, was plotted (figure C1-1). For sake of comparison, figure C1-2 shows the discrete-point approach's depiction of the boundary combined with the Digital Terrain Model's depiction. This illustrates the ability to remove hidden lines when working with a DTM.

An alternative to clearcut harvesting is a partial removal of the stand. Eighty percent of the timber could be cut, as long as skyline corridors of satisfactory width are cleared to facilitate logging. The remaining timber will provide a shelterwood effect to the regenerating stand, and may be removed in seven to ten years without intolerable damage to the new stand. The visual effect will be one of texture modification and possibly a linear effect from the skyline corridors, rather than the more pronounced impact of form seen in the clearcut alternative. Figure C1-3 is a PERSPECTIVE PLOT depiction of the partialcut alternative. Although the textural break between unharvested and harvested timber is noticeable, the 20% residual stand is a fairly unbroken forest canopy. Few of the forty-foot-wide skyline corridors are highly visible. except for several at the right-hand edge of the stand (at Azimuth 360). Figure C1-4 is additional information obtained from the DTM -- skyline profiles used for payload analysis. Although the degree of accuracy for these profiles is not high, they will allow a rough computation of skyline payloads, and will indicate problem spots where more accurate field work will pay off.

Further exploration might be possible for this project. For example, the harvest unit size could be reduced or the shape changed. Or, a different intensity of partial-removal harvest could be tried. Or, in anticipation of some percentage of blowdown within a year or two of partial-removal harvest, the stand could be simulated with a lower stocking level.

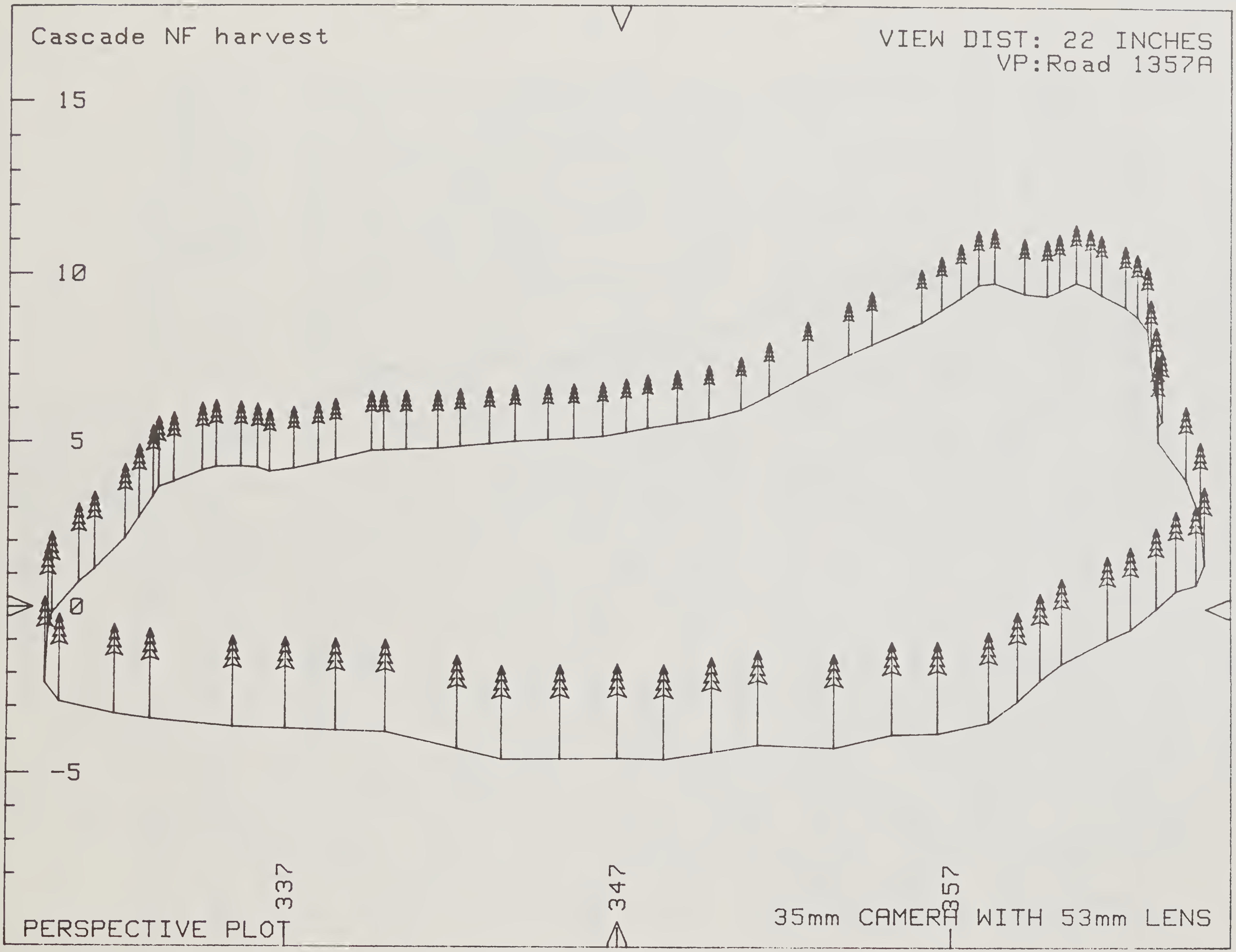


Figure C1-2. The clearcut activity shown in figure C1-1, as a discrete-point approach would portray it. The screening afforded by the ridge is not shown, and the form and scale of the activity may be misjudged from this image.

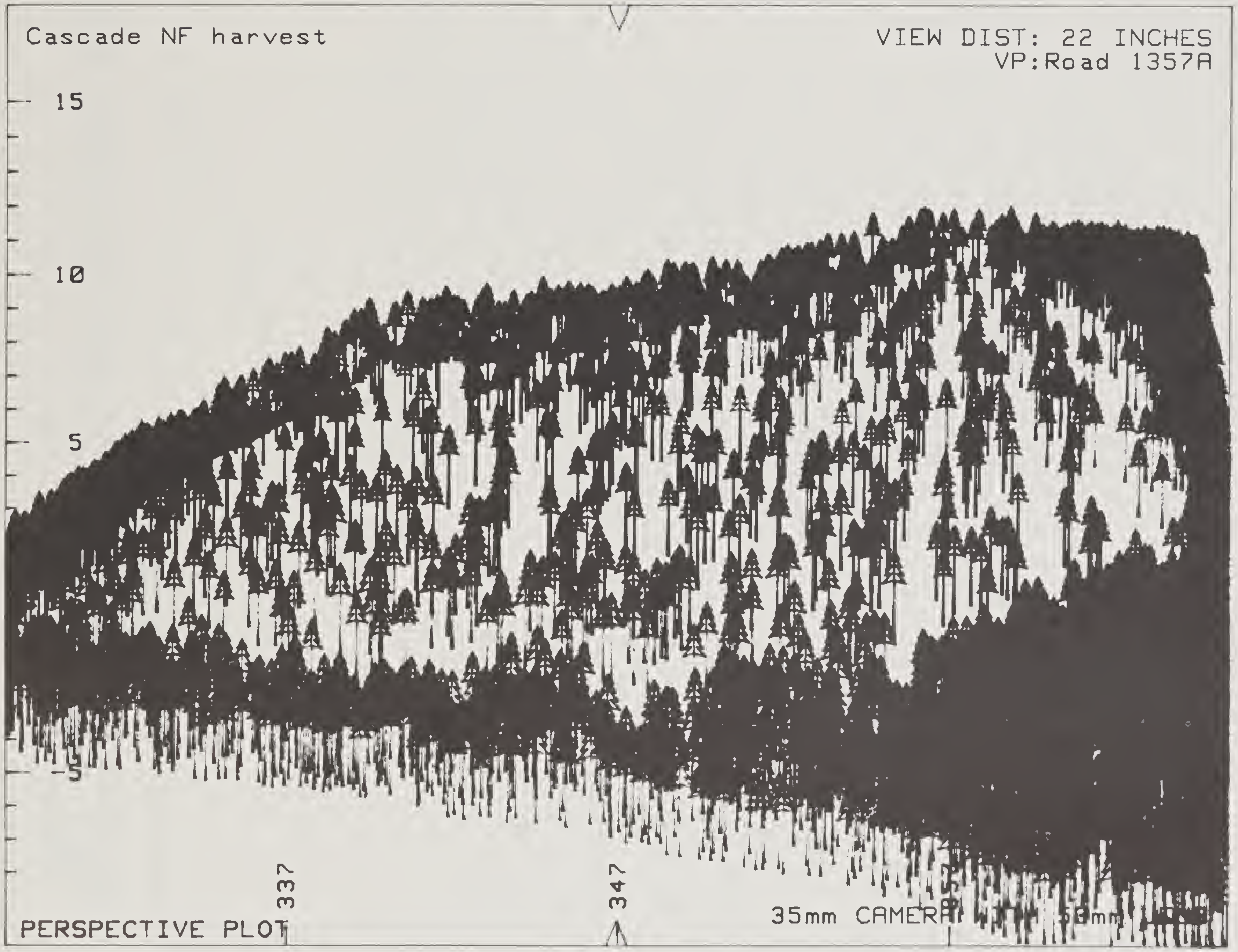


Figure C1-3. A partialcut (shelterwood) alternative to the clearcut activity. Forty-foot-wide skyline harvest corridors are shown, radiating from a ridge-top landing.

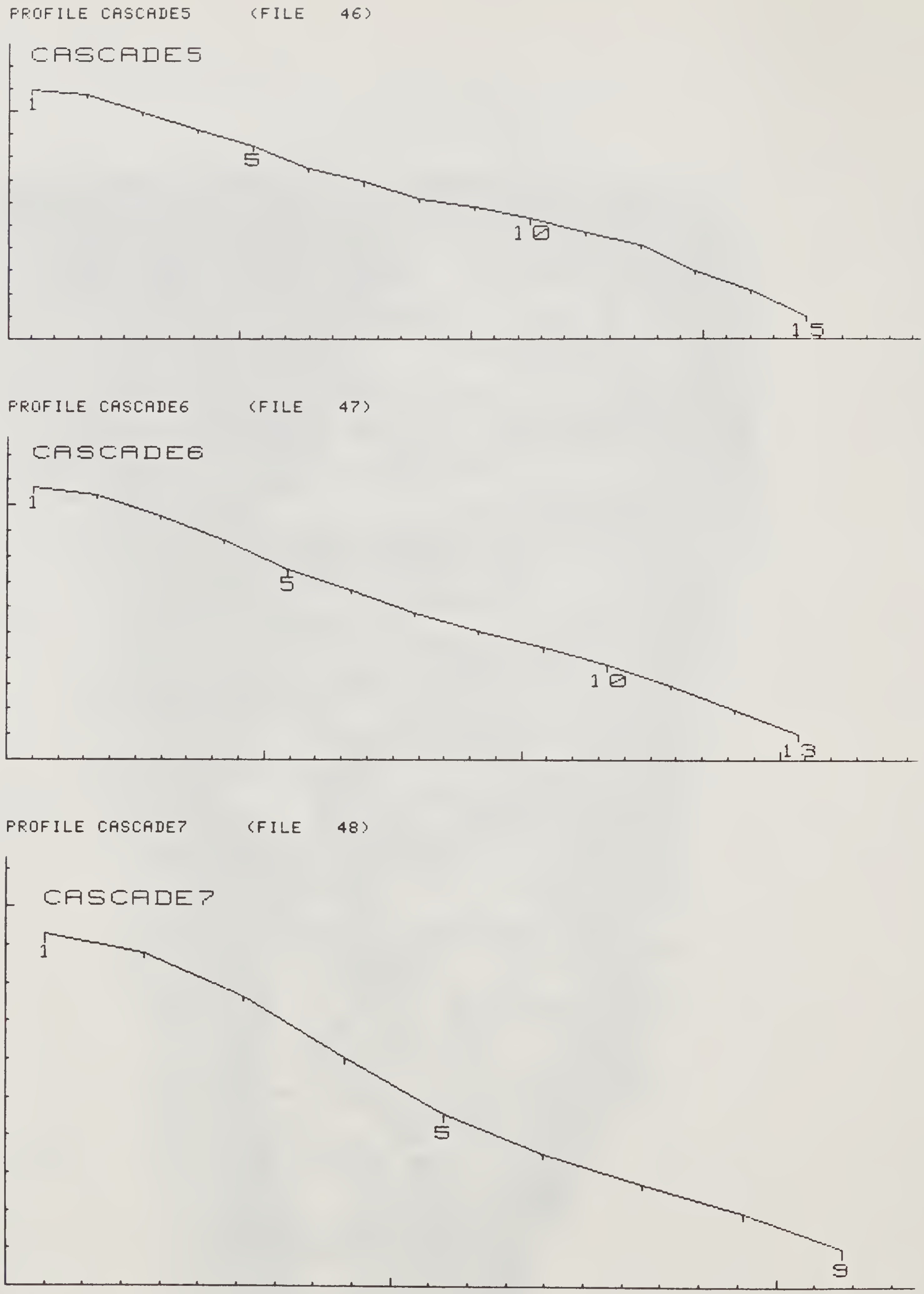


Figure C1-4. Skyline corridor profiles derived from the Digital Terrain Model. These will be used to compute permissible payloads for proposed logging machines.

Steps in obtaining CASE STUDY 1 graphics

	Section
Startup	B1
Feature from Digital Terrain Model	B5
Retrieving a Digital Terrain Model	B19
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-square Terrain Base	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Clearcut harvest boundary	
Choose Program Branching Option	B14
Discrete-point Feature -- Digitizer	B2
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 3 -- Pen color and line type changed to show hidden lines removed by DTM approach.	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Partialcut Timber Stand Boundaries	B10
Partialcut Timber Stand Depiction	B11
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 4 -- Partialcut Harvest Simulation	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Analysis of Terrain Attributes	B21
Output No. 5 -- Skyline Profiles	

CASE STUDY 2 -- Proposed Water Storage Tank
Nevada

The community of Bone Dry, Nevada, is plagued with an unreliable water supply. The City Engineer has made application to the Bureau of Land Management for a Special-Use Permit, covering the construction of an access road and concrete water storage tank. The tank will be cylindrical, 25 feet high and 40 feet in diameter.

PERSPECTIVE PLOT was used to model the visual impact of the tank, access road, cut and fill slopes, and right-of-way clearing as seen from a nearby viewpoint. The tank itself was depicted, using closely-spaced 25-foot "trees" with a crown width of zero. Exact elevations of points along the road shoulders were necessary, since these points are above or below the natural ground line.

Figure C2-1 shows the resulting graphic. The original was plotted on transparent acetate, with the right-of-way clearing limits prepared as a separate overlay.

The City Engineer can work with the BLM Landscape Architect to revise the proposal, if necessary. They may wish to relocate the road, redesign the tank, or look at the project from a different vista point. Once the "design" work has been completed, the final graphic may be given to an artist, so that a realistic drawing such as figure C2-2 may be prepared.

Steps in obtaining CASE STUDY 2 graphics

	section
Startup	B1
Discrete-point Feature -- Digitizer	B2
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Road, Cut/fill Limits, Storage Tank	
Choose Program Branching Option	B14
Discrete-point Feature -- Digitizer	B2
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Clearing limits plus 40-foot Pinyon-Juniper-Ponderosa timber	

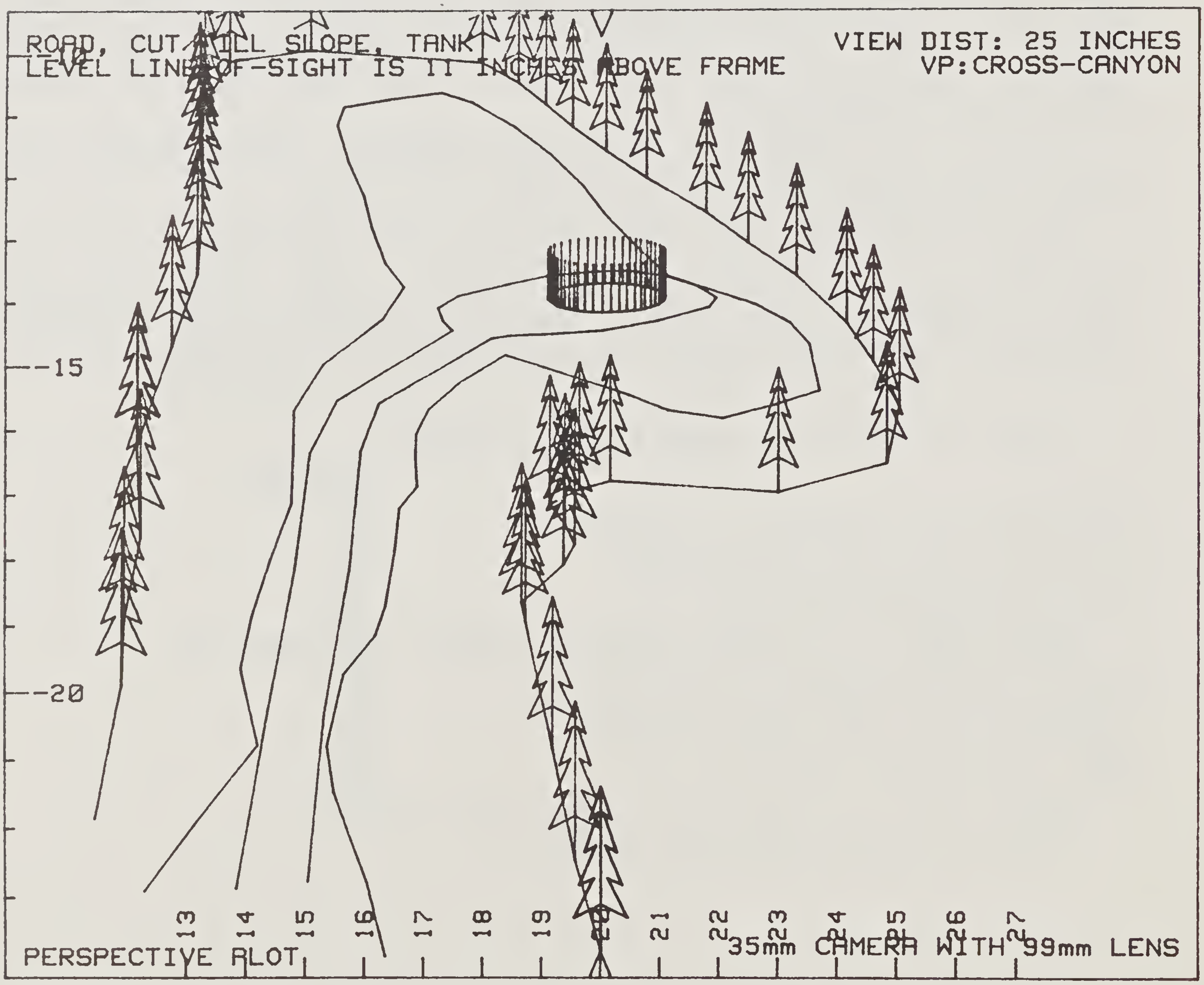


Figure C2-1. Perspective depiction of water storage tank, access road, earthwork, and clearing limits.

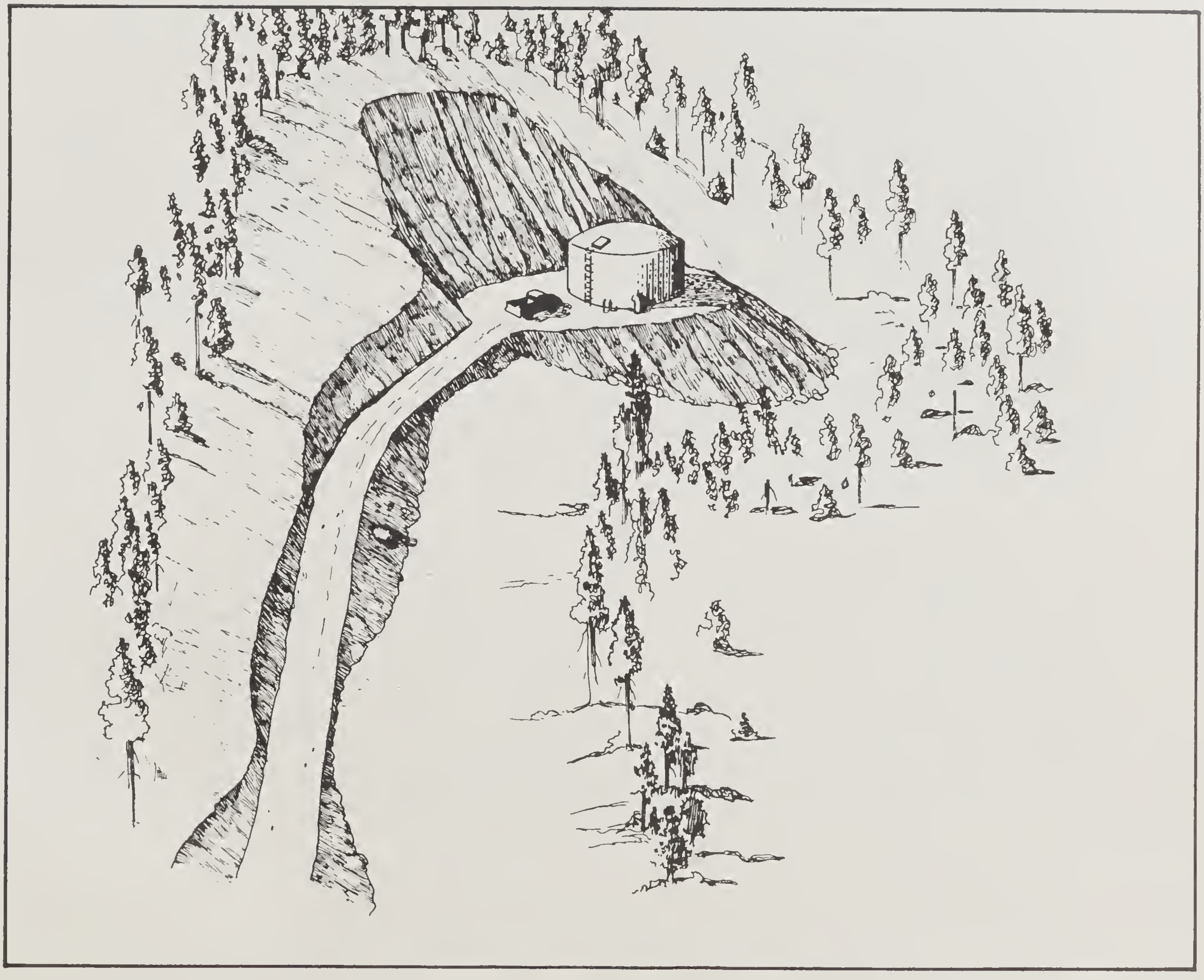


Figure C2-2. When design work, using PERSPECTIVE PLOT simulations, has arrived at a satisfactory proposal, an artist's rendering can be produced. Fine detail can be portrayed in a realistic fashion, yet with geometric correctness derived from the perspective depiction.

CASE STUDY 3: Highway Vista
Private Timberlands
Washington

A large timberland-management company in western Washington state has plans to clearcut harvest a 67-acre block of mature Douglas-fir timber. Being progressive in its attitude toward scenic quality in highly-visible forested landscapes, the company has asked a Landscape Architecture consulting firm to assess the visual impact of the planned harvest.

A major state highway directs the motorist's view toward the timber harvest area along a 2-mile tangent. This suggests a prolonged viewer exposure to the activity, with a changing perceived form and scale as the motorist moves closer.

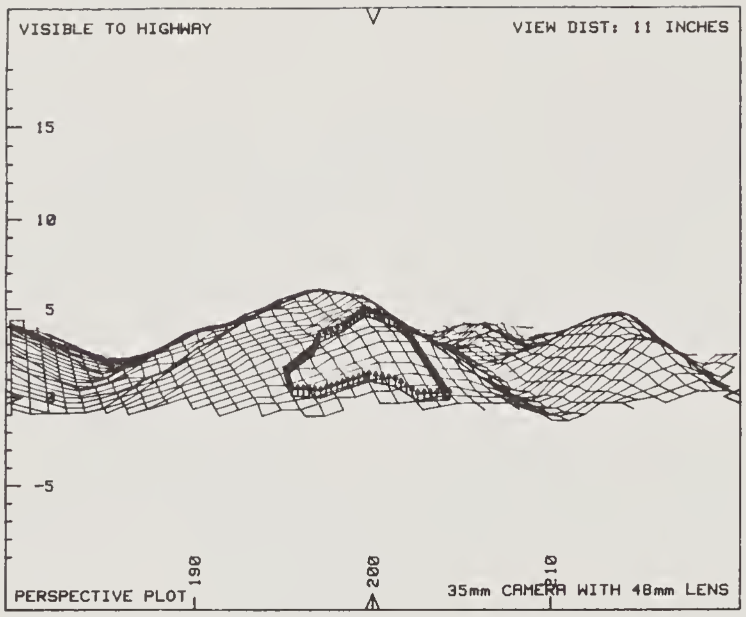
A series of PERSPECTIVE PLOT outputs were generated, representing the motorist's view every 15 seconds. View direction was kept more-or-less tangent to the highway alignment. Width-of-field was kept to 48mm, corresponding approximately to comfortable human peripheral vision. Vertical angle was held to 5 degrees above level. These line-of-sight parameters kept the visual models close to the images a motorist would see, travelling at highway speeds and paying a reasonable amount of attention to the road ahead.

Figure C3-1 shows the succession of images. The first figure is a combination of harvest activity boundary and distorted-square terrain base. This gives a comparison between the scale of the activity and the surrounding landforms (the same combination could easily have been prepared for each successive view). As the viewer moves closer to the harvest area, its form is altered substantially, as well as the scale in which it is perceived.

Should the long-duration sequence of views be an intolerable affront to the tourist's tastes, the consultant could suggest alternate boundary configurations that might tone down the impact or make it appear less unnatural, considering the landforms it would be set against. "Hiding" the harvest activity is unlikely, given the orientation of the highway and terrain. Foregoing the harvest opportunity is equally unlikely, given the corporate responsibilities of the landowner. The constructive alternative is to ameliorate the visual effects within the framework of design latitude.

Steps in obtaining CASE STUDY 3 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Constructing a Digital Terrain Model	B17
Storing a Digital Terrain Model	B18
Choose Digital Terrain Model Output	B20
Distorted-square Terrain Depiction	B9
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-square Terrain Base for Frame 1	
Choose Program Branching Options	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flatbed Plotter Outputs (without changing paper on plotter)	B15
Harvest activity added to Frame 1 graphic	
Choose Program Branching Options (new VP)	B14
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Subsequent Outputs -- Frames 2 - 8	



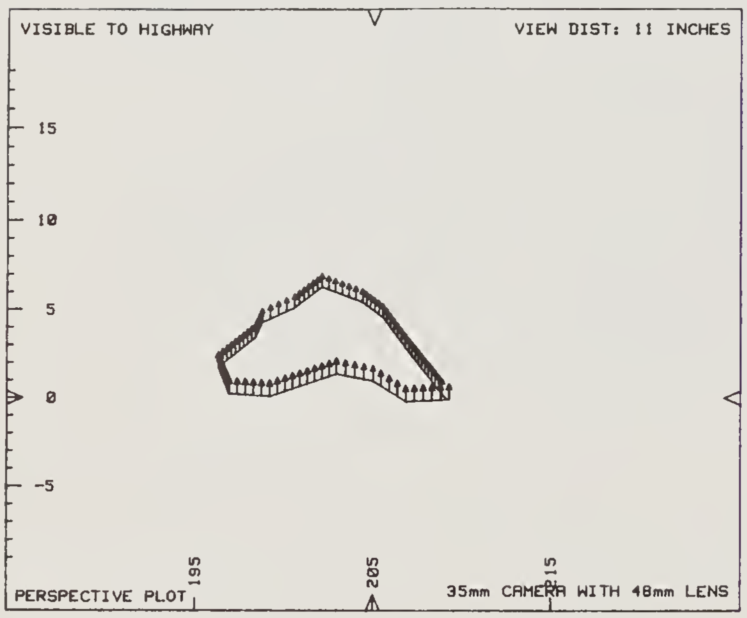
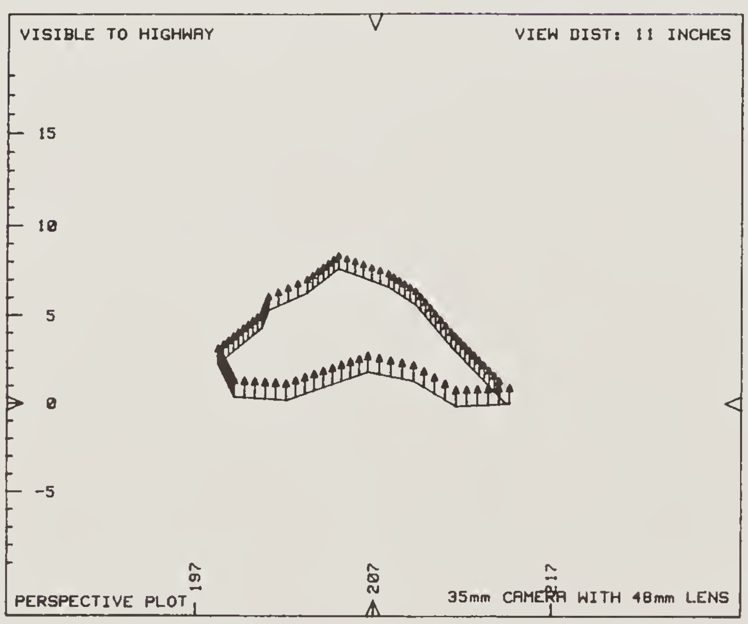
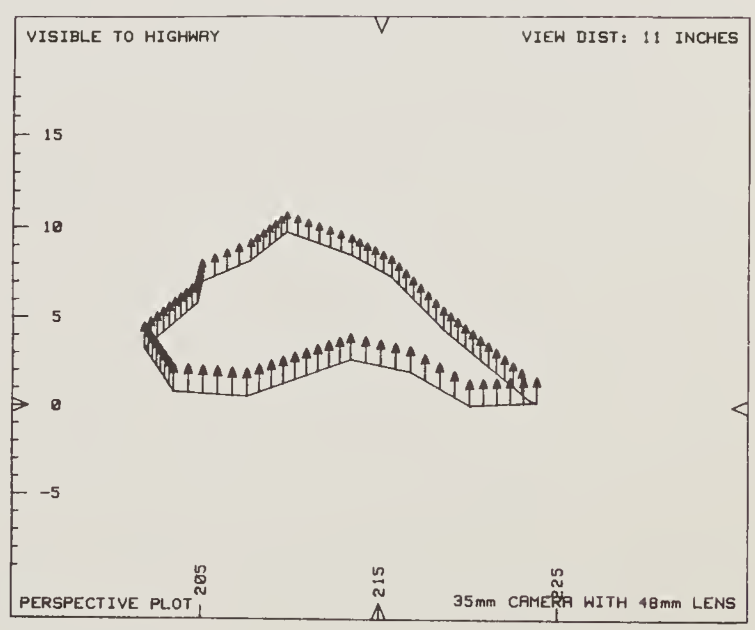
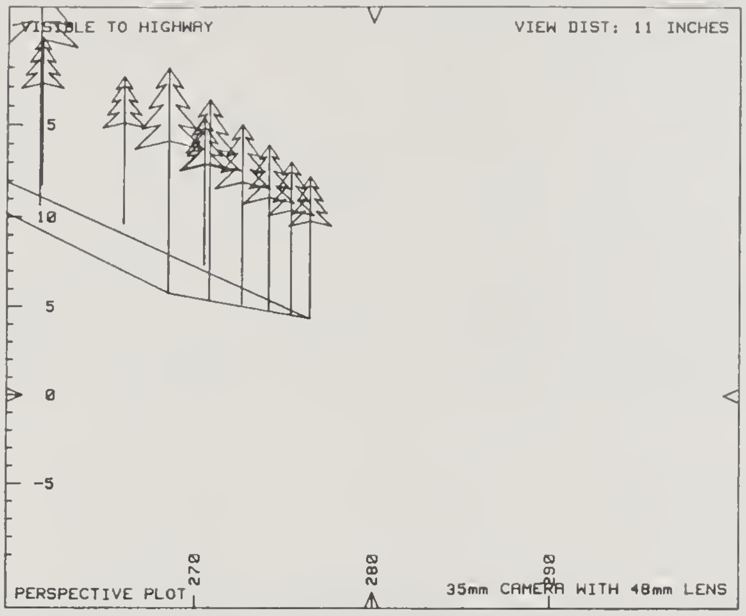
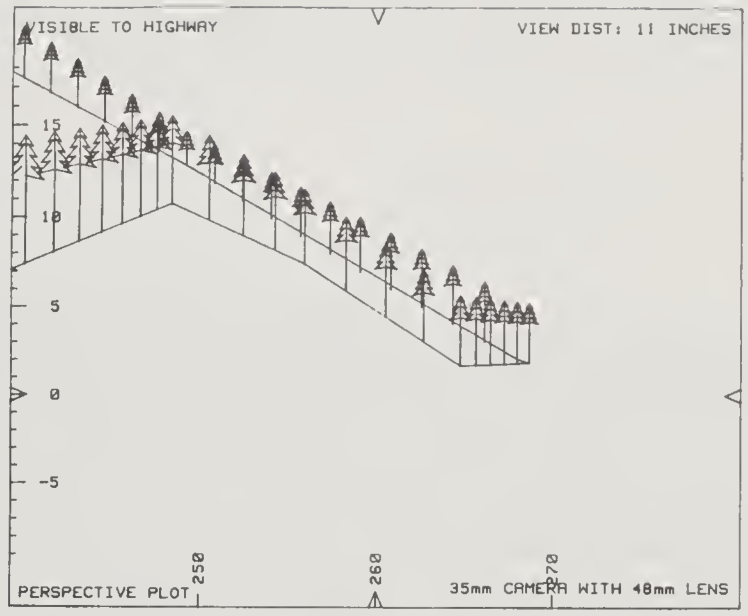


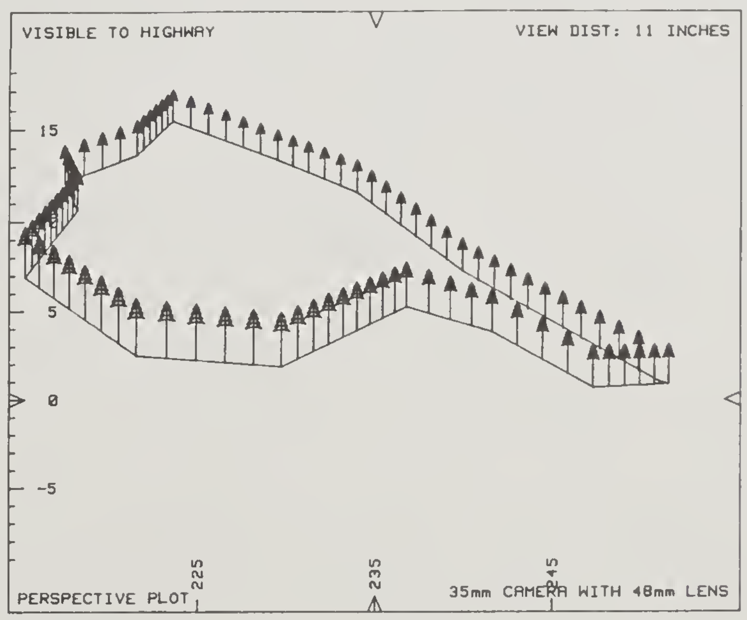
Figure C3-1. The sequence of images seen by a motorist approaching the proposed harvest area. Form and scale alter radically as the view point changes. Each fram is separated by about fifteen seconds travel time.

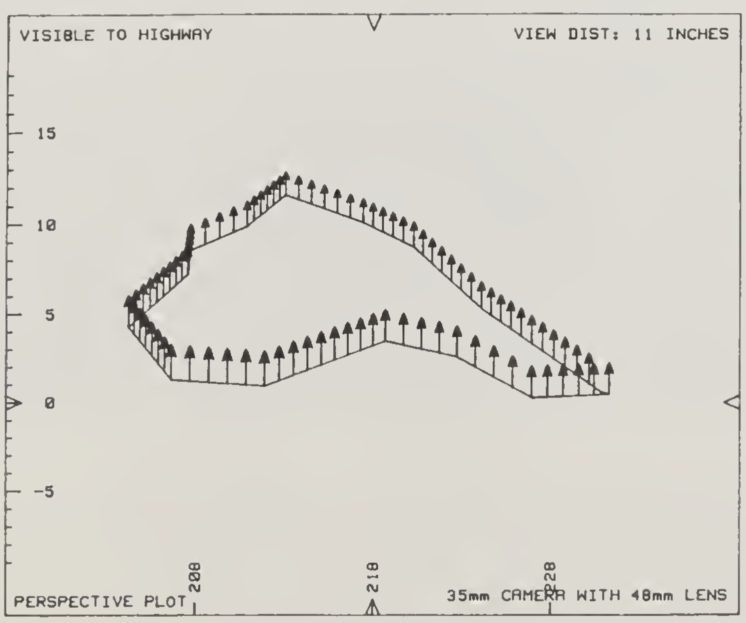





VISIBLE TO HIGHWAY
VIEW DIST: 11 INCHES
5
10
5
0
-5
270
280
290
PERSPECTIVE PLOT
35mm CAMERA WITH 48mm LENS


VISIBLE TO HIGHWAY
VIEW DIST: 11 INCHES
15
10
5
0
-5
250
260
270
PERSPECTIVE PLOT
35mm CAMERA WITH 48mm LENS


VISIBLE TO HIGHWAY
VIEW DIST: 11 INCHES
15
5
0
-5
225
235
245
PERSPECTIVE PLOT
35mm CAMERA WITH 48mm LENS


VISIBLE TO HIGHWAY
VIEW DIST: 11 INCHES
15
10
5
0
-5
208
218
228
PERSPECTIVE PLOT
35mm CAMERA WITH 48mm LENS

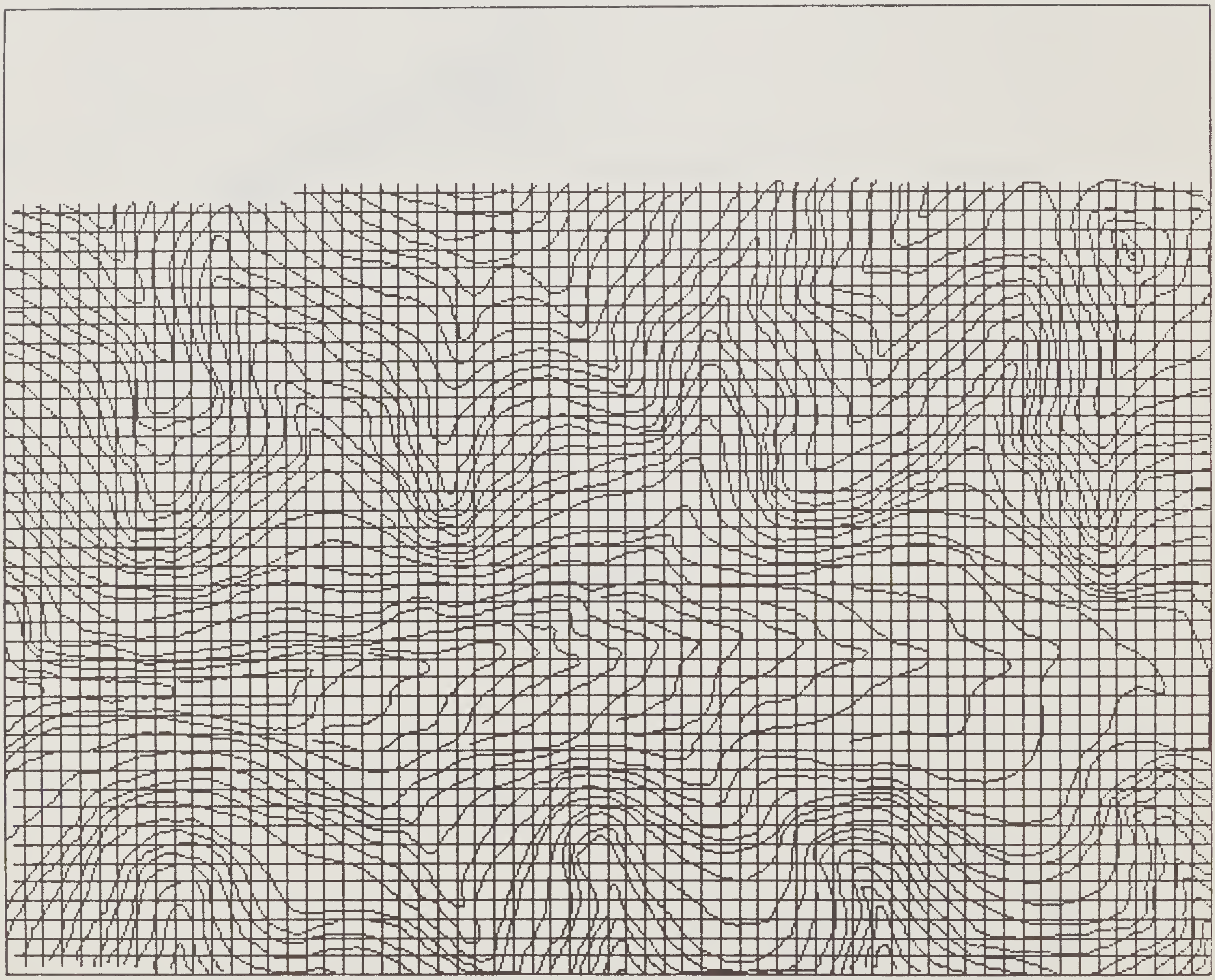


Figure C4-1. Digital Terrain Model of private timberland ownership in South Carolina.

CASE STUDY 4 -- Digital Terrain Model Attributes South Carolina

A Digital Terrain Model was produced that encompassed 2340 acres of privately-owned hilly forest land in South Carolina (figure C4-1). As one management option, the landowner is considering establishment of an exotic hardwood species with extremely high pulpwood production potential. Climatic factors indicate the species will do best on midslope elevations (1000 - 1500 feet above sea level) and on south-facing slopes. The area's soil is unstable on slopes over 90%, making timber harvest unfeasible in these regions. Terrain over 30% slope must be logged by cable systems, rather than less costly tractor logging. The landowner wants to know:

1. How much acreage is unsuitable for timber production?
2. How much acreage is suitable for establishment of exotic hardwood plantation?
3. How much acreage with hardwood plantation potential must be cable logged? (total acreage and distribution into unbroken blocks is central to the economic decision to proceed with establishing the plantations.)

<u>PERSPECTIVE PLOT</u> was used to extract summaries of terrain attributes that help answer these questions. The summaries are in the form of graphics showing shading over that portion of the DTM possession the desired attribute. The graphics are to the same scale as the thermal-printer replica of the DTM, and can be photocopied on transparent stock, to be used as overlays.

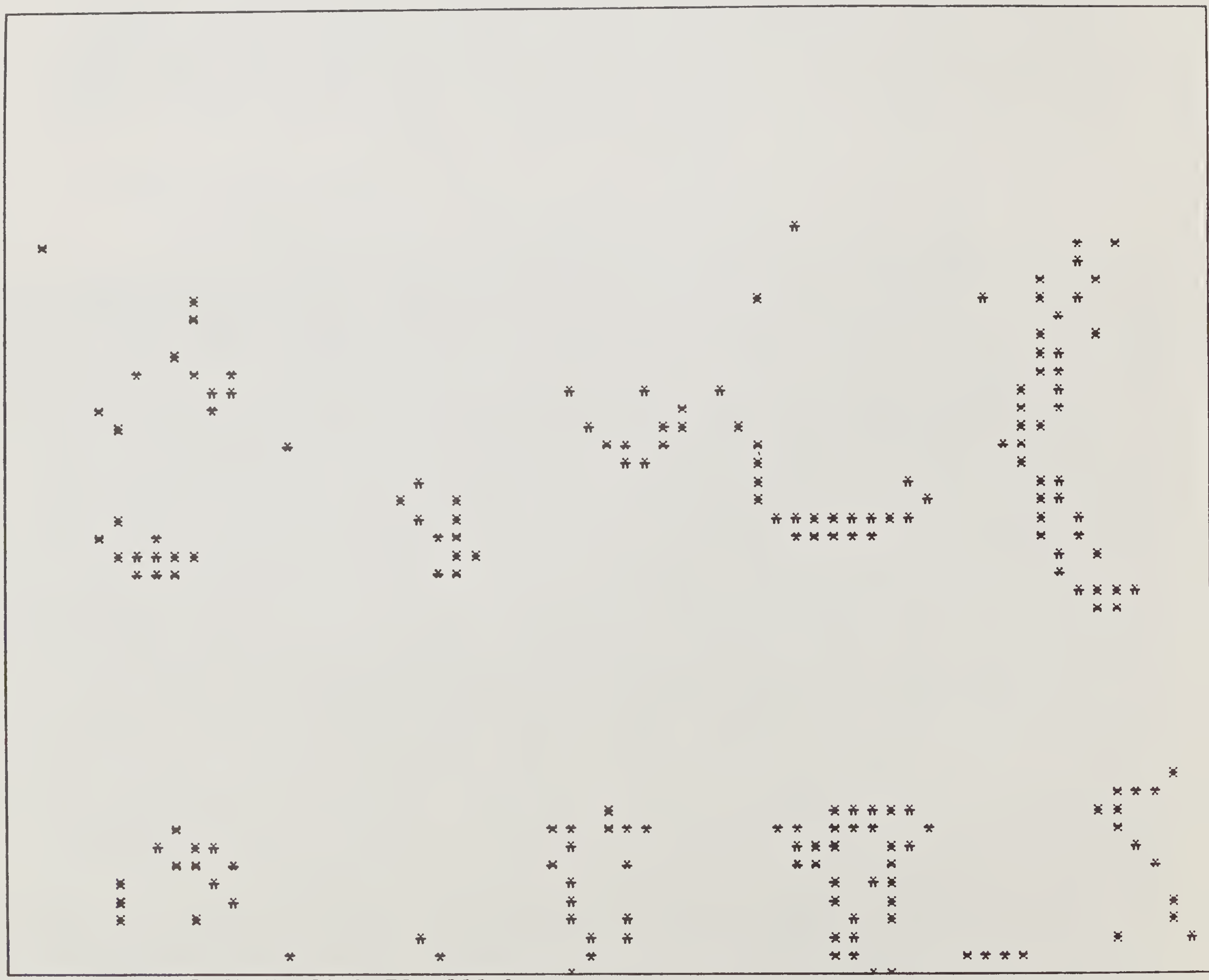
Figure C4-2 shows areas of slope in excess of 90%, totalling 163 acres, or 7% of the ownership. In some areas, the distribution is in small scattered parcels, so some part of this land could be managed with low risk of mass soil failures.

Figure C4-3 shows areas lying between 1000 and 1500 feet elevation, with southern aspects (between 135 and 225 degrees azimuth). This comprises 197 acres or 8 % of the ownership, and is in fairly unbroken blocks, suitable for plantation management. Somewhat larger blocks could be delineated, absorbing small included areas not identified by the computer due to terrain irregularities slightly outside the attribute limits selected.

Figure C4-4 shows areas possessing the previously-listed elevation and aspect characteristics, with slopes in the 30% to 90% range. These 142 acres must be planned for cable logging. The distribution is fairly suitable for small cable harvesting systems; the landowner can locate landings and haul roads, and cost out this option.

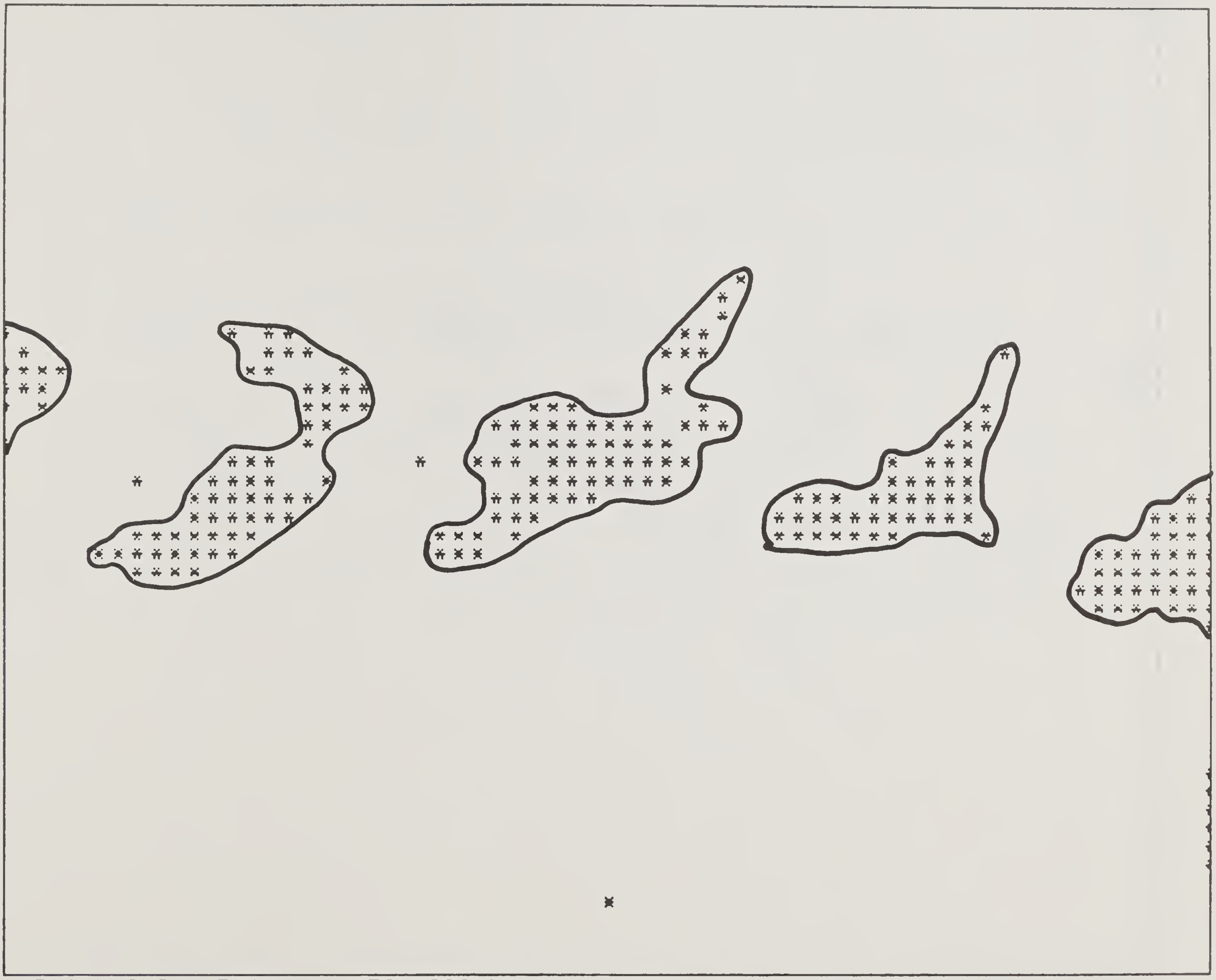
Similar extracts of terrain attributes from other forest lands could answer management questions on:

* Silvicultural or vegetation-management considerations
* Wildfires: rate-of-spread, hazard reduction, resistance to control
* Hydrology and soils: erosion potential, snow accumulation, potential evapotranspiration
* Timber harvest planning and logging systems selection



TERRAIN SLOPE FROM 90 % TO 300 %
ACRES POSSESSING THIS ATTRIBUTE: 162.7
TOTAL ACREAGE IN THIS DTM: 2339.5

Figure C4-2. Terrain slope overlay.

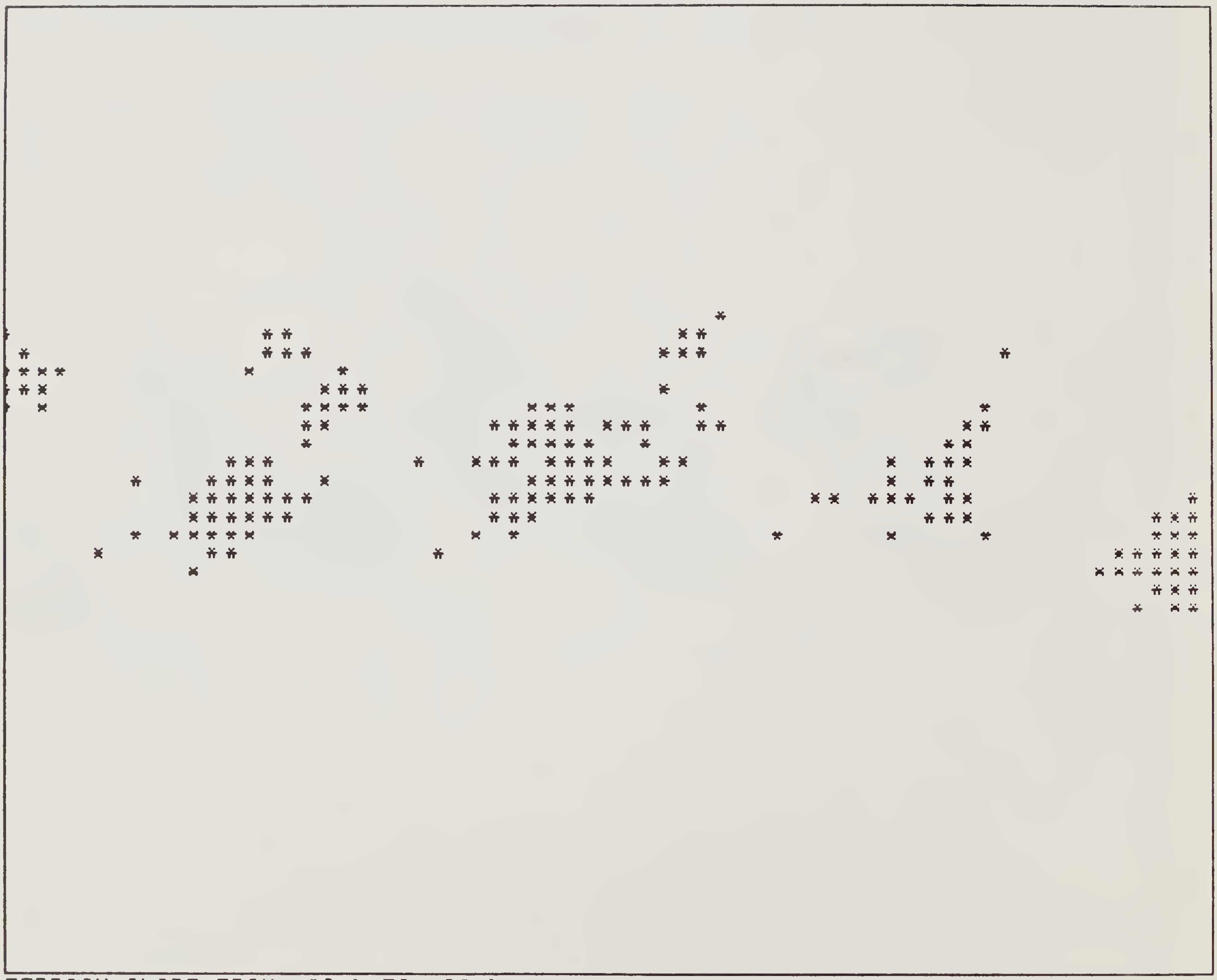


TERRAIN SLOPE FROM 0 % TO 300 %
TERRAIN ASPECT BETWEEN 135 DEGREES AND 225 DEGREES AZIMUTH
TERRAIN ELEVATION BETWEEN 1000 FEET AND 1500 FEET

(AZIMUTH 0)

ACRES POSSESSING THIS ATTRIBUTE: 196.7
TOTAL ACREAGE IN THIS DTM: 2339.5

Figure C4-3. Terrain elevation and aspect overlay.



TERRAIN SLOPE FROM 30 % TO 90 %
TERRAIN ASPECT BETWEEN 135 DEGREES AND 225 DEGREES AZIMUTH
TERRAIN ELEVATION BETWEEN 1000 FEET AND 1500 FEET

(AZIMUTH 0)

ACRES POSSESSING THIS ATTRIBUTE: 141.6
TOTAL ACREAGE IN THIS DTM: 2339.5

Figure C4-4. Terrain slope, elevation and aspect overlay.

* Recreation potential (one study used slope zones to identify areas for potential development of ski runs of graduated difficulty levels)
* Wildlife habitat identification: winter range, cover preferences, calving areas, preferred browse distribution
*Visual Absorption Capability (an estimate of the terrain's ability to absorb visual modification without intolerable effects on the viewer -- slope, aspect and elevation relative to the viewer play a major part)

<u>Steps in obtaining CASE STUDY 4 graphics</u>

	section
Startup	B1
Feature from Digital Terrain Model	B5
Retrieving a Digital Terrain Model	B19
Output No. 1 -- Digital Terrain Model Thermal-printer Replica	
Choose Digital Terrain Model Output	B20
Analysis of Terrain Attributes	B21
Choose Program Branching Option	B14
Output No. 2 -- slope attribute overlay	
Choose Program Branching Option	B14
Output No. 3 -- slope/aspect/elevation attribute overlay	
Choose Program Branching Option	B14
Output No. 4 -- slope/aspect/elevation attribute overlay	

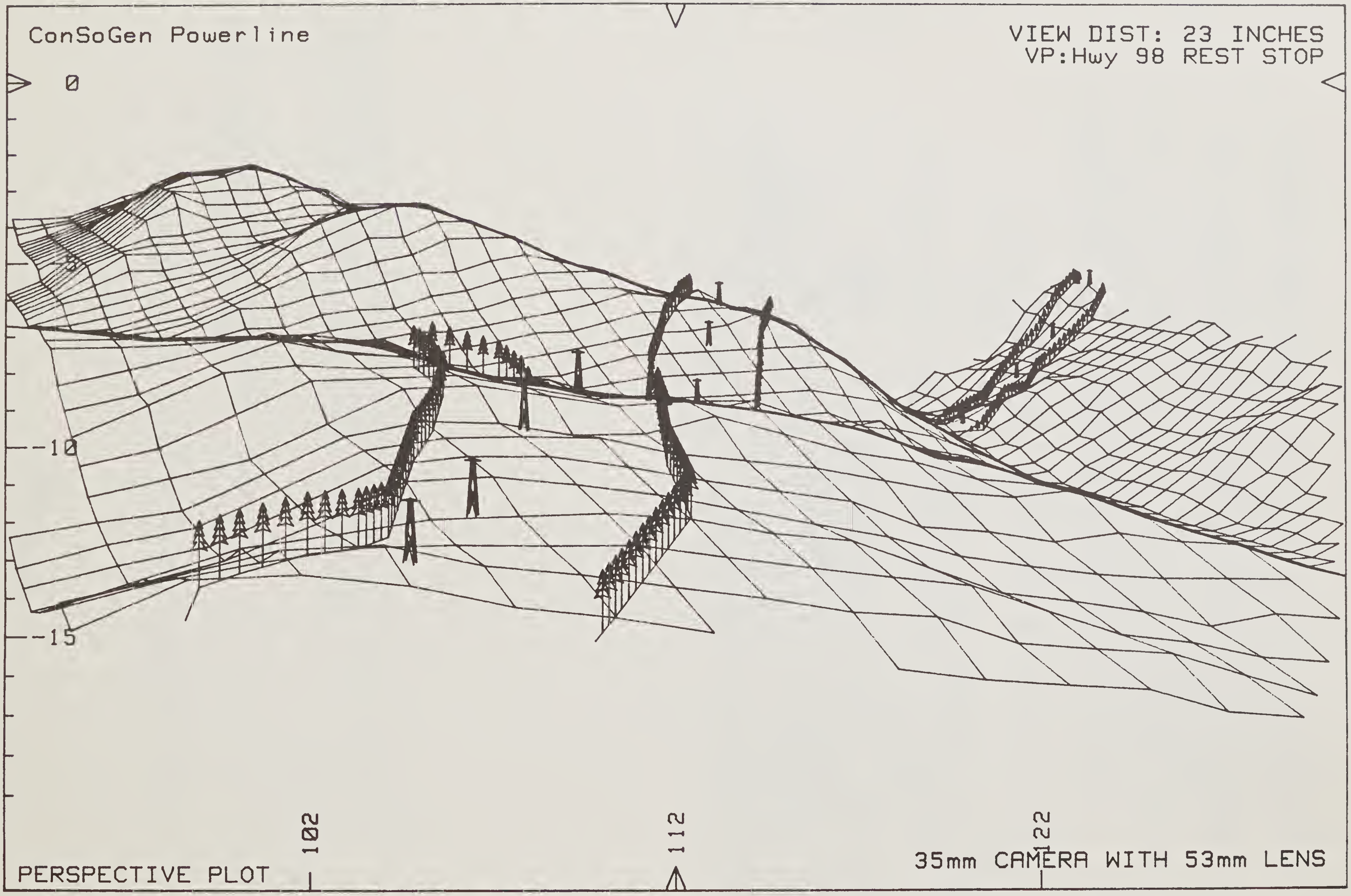


Figure C5-1. A portion of the powerline right-of-way crosses the far ridge, dips into a draw, and approaches the viewer on the foreground ridge. The clearing width and structure scale may be judged from this viewpoint, based on this simulation.

CASE STUDY 5 -- Proposed Electric Transmission Line
California

Consolidated Southern California General Gas & Electric Company has a pressing need to tie its new Lake Tahoe Nuclear Facility into the Southwest Power Grid. The company has been granted a license to construct a 1.5 MV transmission line across the Sierra Nevada mountains. Certain stretches of the powerline clearing will be visible in landscapes currently managed for retention of high scenic quality. The Outdoor Coalition -- a conservation-minded citizen's watchdog group -- is understandably interested in assessing the visual impact of ConSoGen's planned route and proposal.

A large number of PERSPECTIVE PLOT simulations were made, showing various points along the route. Figure C5-1 shows one such view -- a composite of three layers plotted on clear acetate:

1. Distorted-square topographic landform base
2. Borders of specified 400-foot-wide corridor clearing
3. Standard 90-foot steel support towers

The visual statement made by the wide right-of-way clearing, as its perceived form and scale fits within the landforms, can be evaluated and discussed by concerned parties. The scale of the support towers, relative to the timber, can be judged as they will be seen in the foreground and on the more distant ridgeline. Artistic enhancement, such as tower detailing, transmission cables and insulators, low vegetation, service roads and structures, may be added within the corridor. Most important, suggested improvements to positioning, support tower design, clearing width, and clearing alignment may be made up as additional overlays, offering constructive suggestions to ameliorate the project's undesireable visual consequences.

Steps in obtaining CASE STUDY 5 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Retrieving a Digital Terrain Model	B19
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-Square Terrain Base	
Choose Program Branching Options	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Borders of Corridor Clearing	
Choose Program Branching Options	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model(modified)	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 3 -- Support Towers	

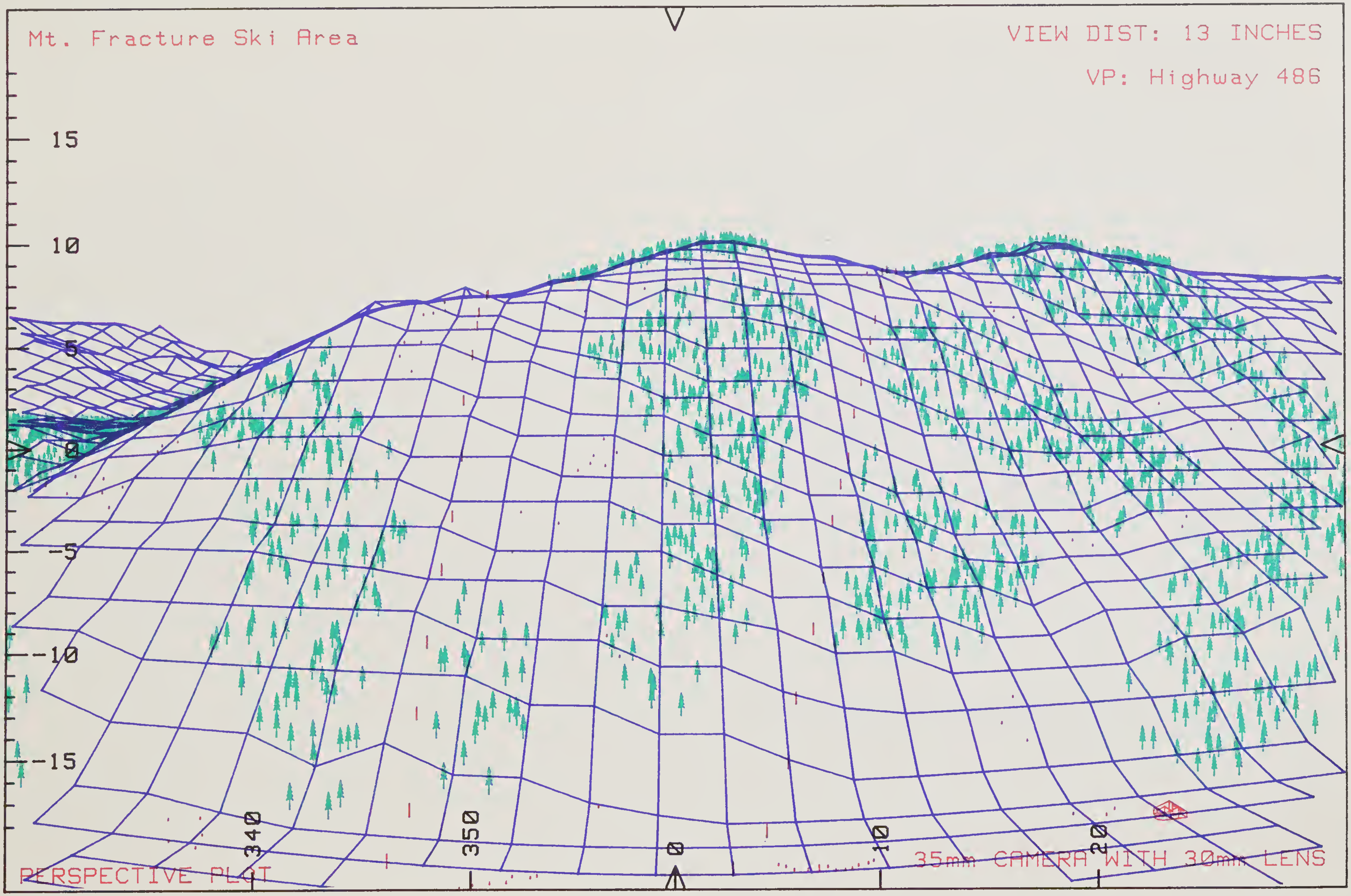


Figure C6-1. Landforms, ski runs, chairlift clearings, lift towers, day lodge, and skier figures combine to illustrate a proposed ski area initial development.

CASE STUDY 6: Proposed Ski Area
Mt. Fracture, Colorado

A consortium of real estate development entrepreneurs has approached the U.S. Forest Service with a proposal to develop and operate a new ski area. The initial phase will involve two major ski lifts and 400 acres of ski runs on the south face of Mt. Fracture. A day lodge will be constructed at the east end of the valley. As part of the concept presentation, the consortium would like a perspective simulation of the initial phase, as seen from a viewer-superior position along State Highway 486.

Forest cover on the south face is a nearly unbroken, uniform stand of coniferous forest. Run and lift clearings will be wide, to offer maximum skier absorption on slopes of moderate difficulty. Nonetheless, an attempt has been made to leave large blocks of timber, and to design ski run clearings to fit within the shapes of the terrain forms.

Three <u>PERSPECTIVE PLOT</u> outputs were obtained, plotted on clear acetate for use as sequential projector overlays. These are:

1. Distorted-square topographic landform base
2. Forest cover remaining after ski run clearing
3. Ski lift support towers, day lodge, and skier figures (for scale comparison)

Figure C6-1 shows these three color graphics in combination. Figure C6-2 is a telephoto "close-up" of the daylodge. A stereo image of the day lodge, seen under a mirror stereoscope, would offer an excellent image from which an artist could work, to produce a conceptual drawing of the structure.

Forest Service landscape architects can judge the acceptability of the proposal's visual impact based on the <u>PERSPECTIVE PLOT</u> output. Should an alternative ski run plan be proposed, this could be prepared as an additional overlay to the same base. Perspective views from different vista points (the terrace of the day lodge, for example) can be easily obtained. Phase two development, which might include additional ski lifts, clearings, or structures, could be arrayed as another overlay.

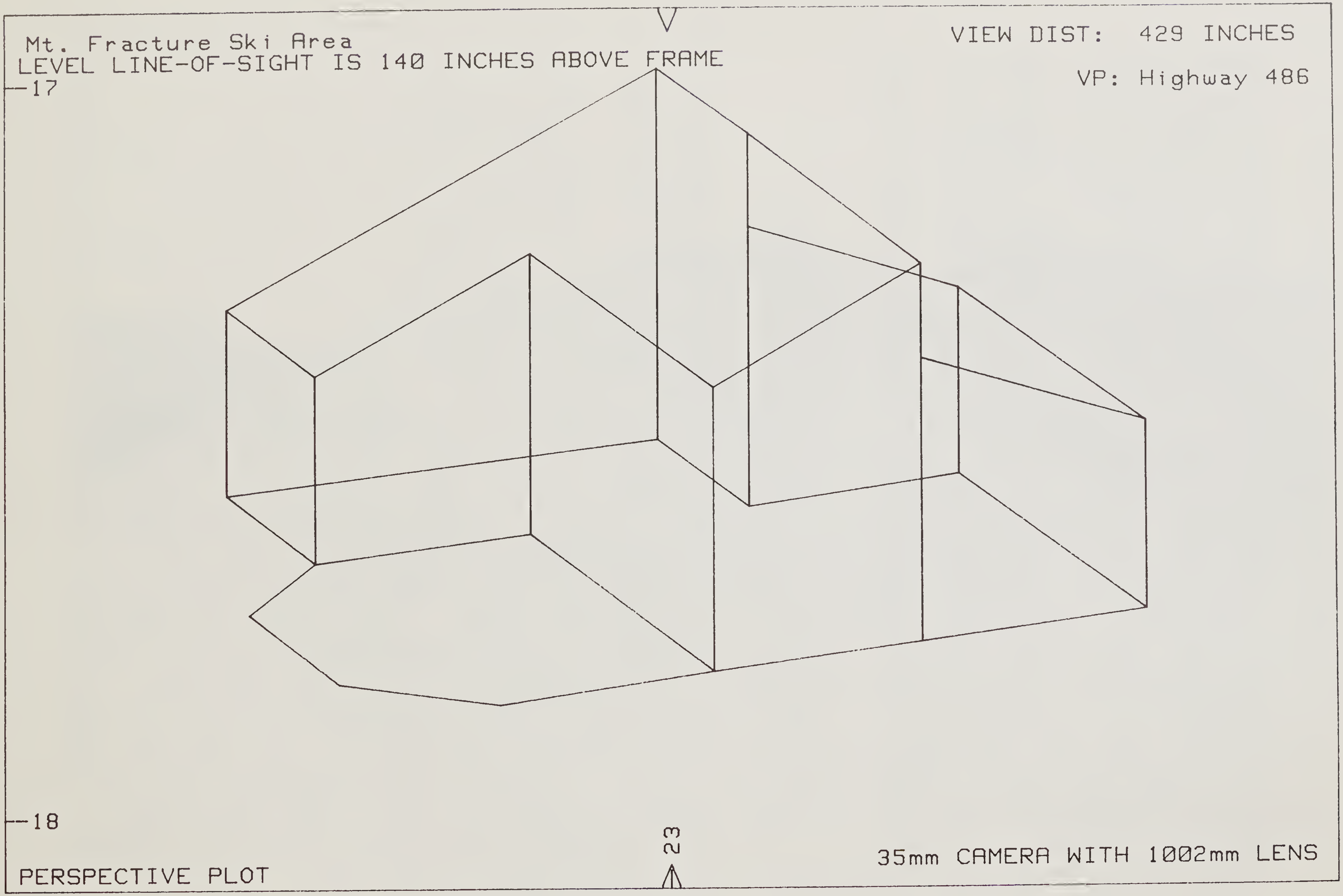


Figure C6-2. Telephoto close-up of the Mt. Fracture Ski Lodge.

Steps in obtaining CASE STUDY 6 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Constructing a Digital Terrain Model	B17
Storing a Digital Terrain Model	B18
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-square Terrain Base	
Choose Program Branching Options	B14
Choose Digital Terrain Model Output	B20
Partialcut Timber Stand Boundaries	B10
Partialcut Timber Stand Depiction	B11
Viewpoint Location	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Forest Cover after Ski Run Clearing	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 3 -- Ski lifts, Day lodge, Skiers	

CASE STUDY 7: Surface Mining (Rock Pit)
Utah

Surface mining operations, including road-construction borrow pits, produce some of the most visually damaging impacts on the landscape. Consequently, when a road construction project on federal land in Utah proposed the development of a small borrow pit as a source of crushed aggregate, PERSPECTIVE PLOT was used to model the visual impact.

A high-quality topographic map was obtained, showing the rocky ridge proposed as the rock pit site. The site was visible from a well-travelled forest road running at an elevation slightly higher than the rock pit site, along the opposite slope of a steep canyon. Distance between a viewpoint selected on the road and the rock pit is less than a quarter-mile. Geotechnical investigation revealed the extent and quality of useable material. Civil engineering supplied information on pit access and the level, size, and shape of maximum-excavation benches. From this information, a topographic pit development plan was drafted. As a final stage, a landscape architect supplied a modified contour map, indicating restoration of the pit site by backfilling with stockpiled rock and topsoil. The effort was to achieve a slightly convex restored landform, in place of the original sharp convex feature.

Three Digital Terrain Models were produced, and corresponding distorted-square terrain depictions were made, seen from the same viewpoint. Figure C7-1 shows the ridge prior to rock pit development. Figure C7-2 shows the access road entering from the left, and the maximum extent of development. Two benches above the pit floor are evident. The limits of excavation, the road surface and cutslope, and the bench levels were made more apparent by preparation of an overlay showing these features. Figure C7-3 shows the terrain after site restoration has been accomplished as proposed.

A mathematical comparison of any two DTMs in this series returns a set of valuable figures: the quantity of excavation involved. Performing this computation reveals the following quantities:

Gross Excavation	73250 cubic yards
Fill required for restoration	38600 cubic yards
Net yield for crushed aggregate	34650 cubic yards

An investigation of available stockpiling locations, pit development sequence, and economic considerations may reveal that it is infeasible to use more than half the pit's gross volume in the restoration. In that case, an alternate restoration plan (involving flatter excavation faces, rounded concave forms, surface replacement of topsoil, and revegetation) might require considerably less material and expense. A distorted-square representation of such an alternative could be generated for comparison purposes.

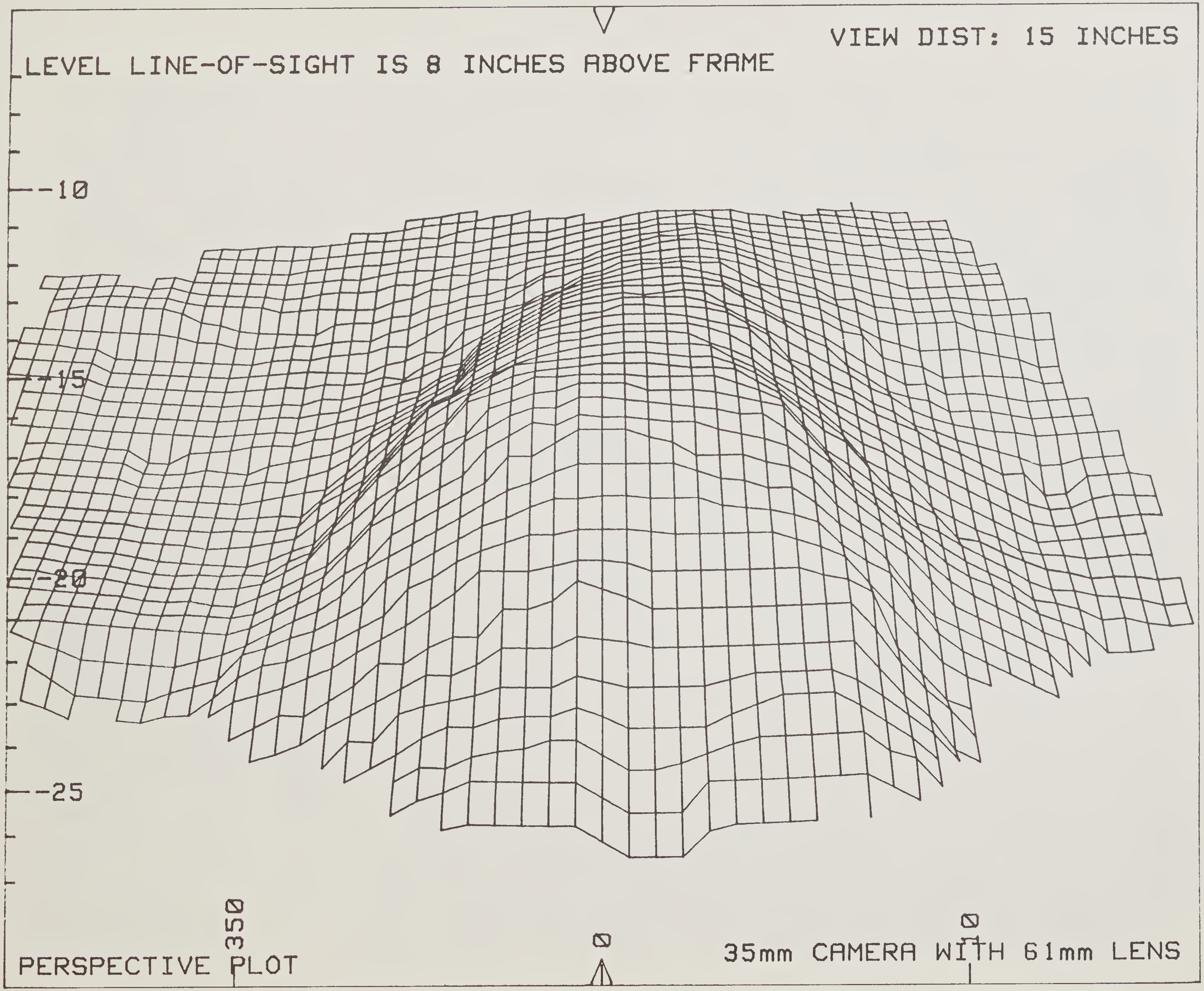


Figure C7-1. Distorted-square depiction of a rock ridge to be developed as a source of road construction material.

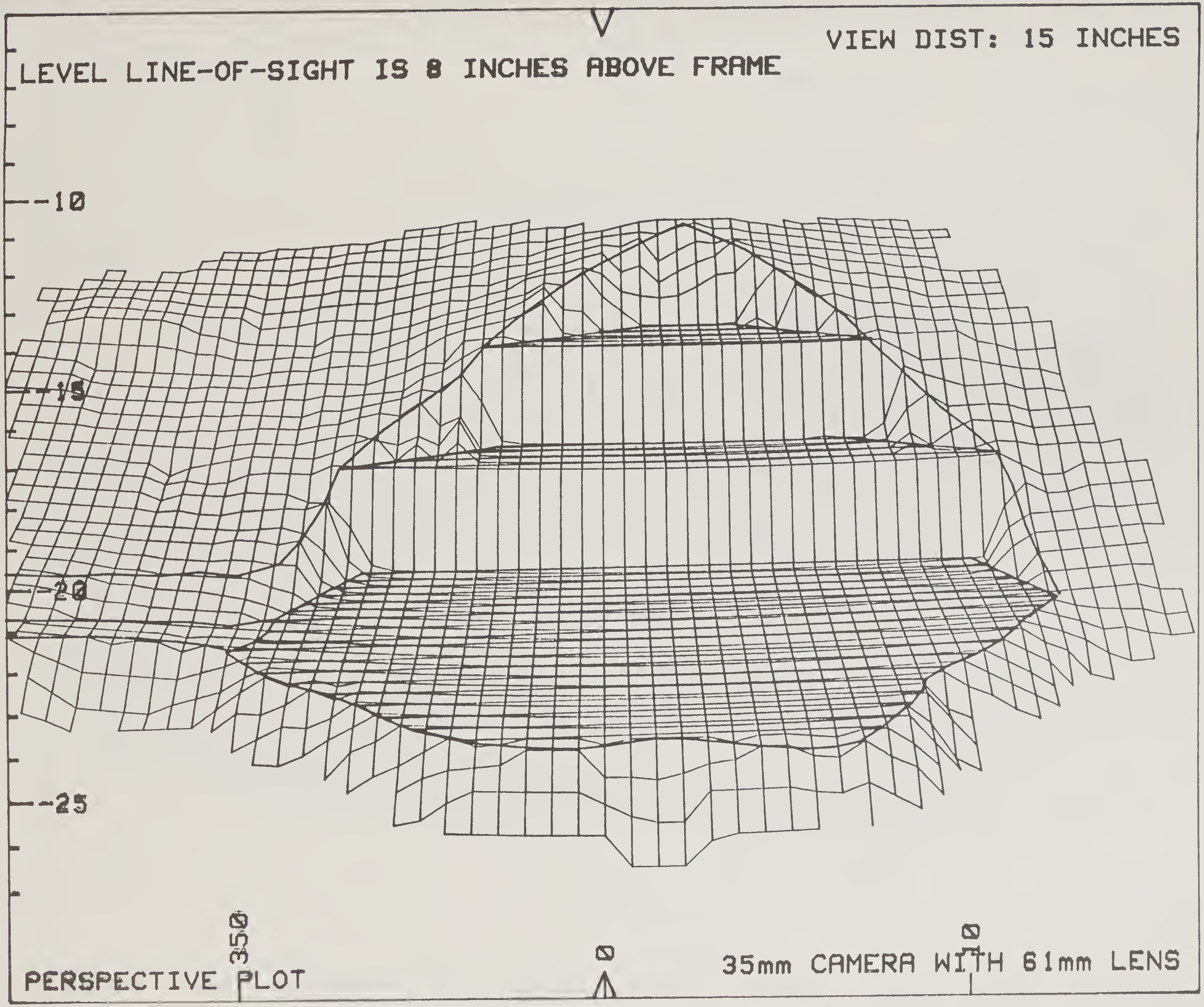


Figure C7-2. The rock pit has been excavated to its maximum extent. Two benches are apparent, above the main pit floor.

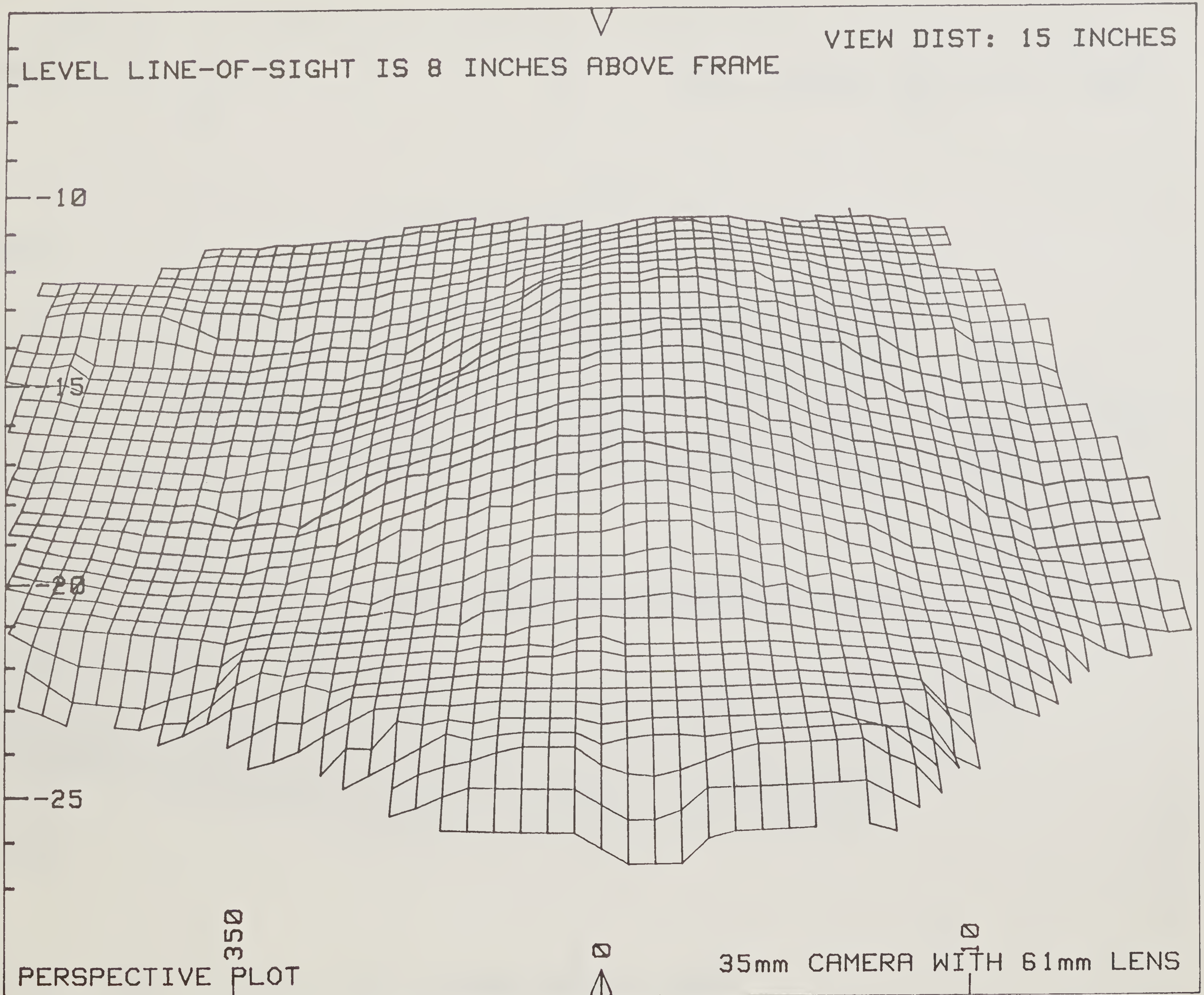


Figure C7-3. One proposal for pit surface restoration. Numerical analysis shows that an excessive amount of material must be devoted to this restoration, prompting the search for a more economical restoration proposal.

Steps in obtaining CASE STUDY 7 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Constructing a Digital Terrain Model	B17
Storing a Digital Terrain Model	B18
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No 1 -- Distorted-Square Terrain before Development (an identical sequence produced the other two distorted-square terrain depictions.)	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Overlay to Output No 2 -- Access road, Benches	

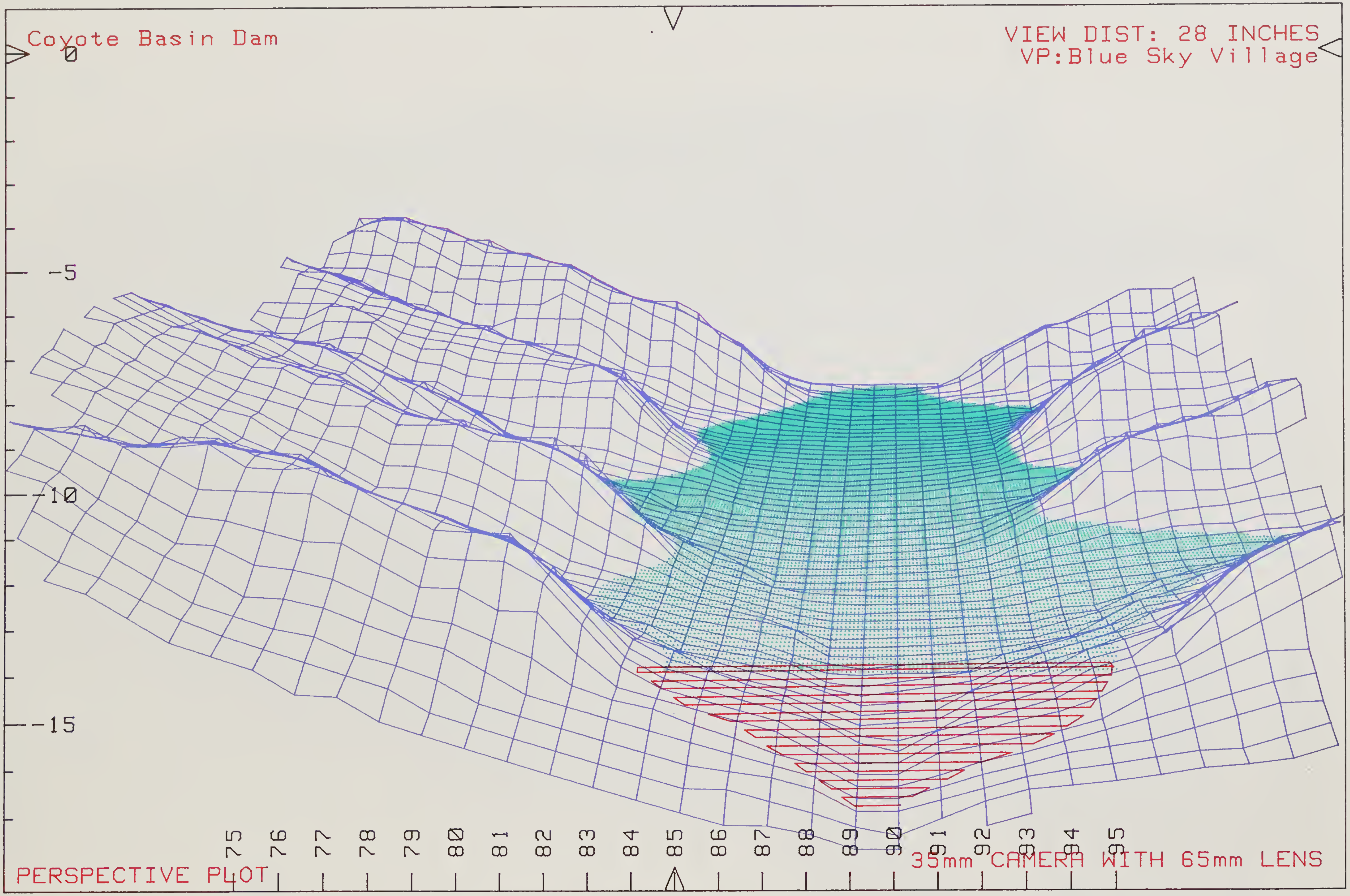


Figure C8-1. Coyote Basin Dam at maximum pool capacity.

CASE STUDY 8: Proposed Hydroelectric Dam
Coyote Basin, Montana

Coyote Basin is a long, broad east-west valley encompassing three square miles drained by Crook River and its tributaries. The mean valley elevation is about 4000 feet. A series of steep ridges and draws define the basin and form a constricted outlet on the west end. The basin is currently unroaded, and the grassy terrain has no present or potential commercial timber-production prospects. Usage is restricted to cattle summer pasture, hunting, primitive camping, and winter ski-touring. The valley is directly visible from the ski resort community of Blue Sky, which lies three miles west at an elevation of 6400 feet.

The Army Corps of Engineers has surveyed an excellent site for a hydroelectric dam. Geotechnical investigation bears out the site's suitability. The resulting impoundment would flood about 1400 acres of Coyote Basin, with a maximum pool capacity of 135,000 acre-feet. Part of the Environmental Impact Statement is a landscape architect's assessment of the project's visual impact on the Blue Sky community.

The PERSPECTIVE PLOT output shown in figure C8-1 is a combination of graphics, showing the distorted-square terrain base, the dam structure, and maximum-pool water surface. The graphics were prepared as sequential overlays on clear acetate, to allow a "before-after" contrast display in Public Involvement meetings. Further simulations would be possible, showing the project from different viewpoints, alternative dam structure configurations, or water level during late-summer drawdown.

One computational spinoff of the Digital Terrain Model portrayal of the lake basin is rapid calculation of reservoir volumes at varying water levels. The same technique could be applied to road-construction earthwork volumes or geomaterial volume computations.

Steps in obtaining CASE STUDY 8 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Constructing a Digital Terrain Model	B17
Storing a Digital Terrain Model	B18
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (CRT cursor)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-square Terrain Base	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Dam Structure	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Partialcut Timber Stand Boundaries	B10
Partialcut Timber Stand Depiction(modified)	B11
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 3 -- Lake Surface	

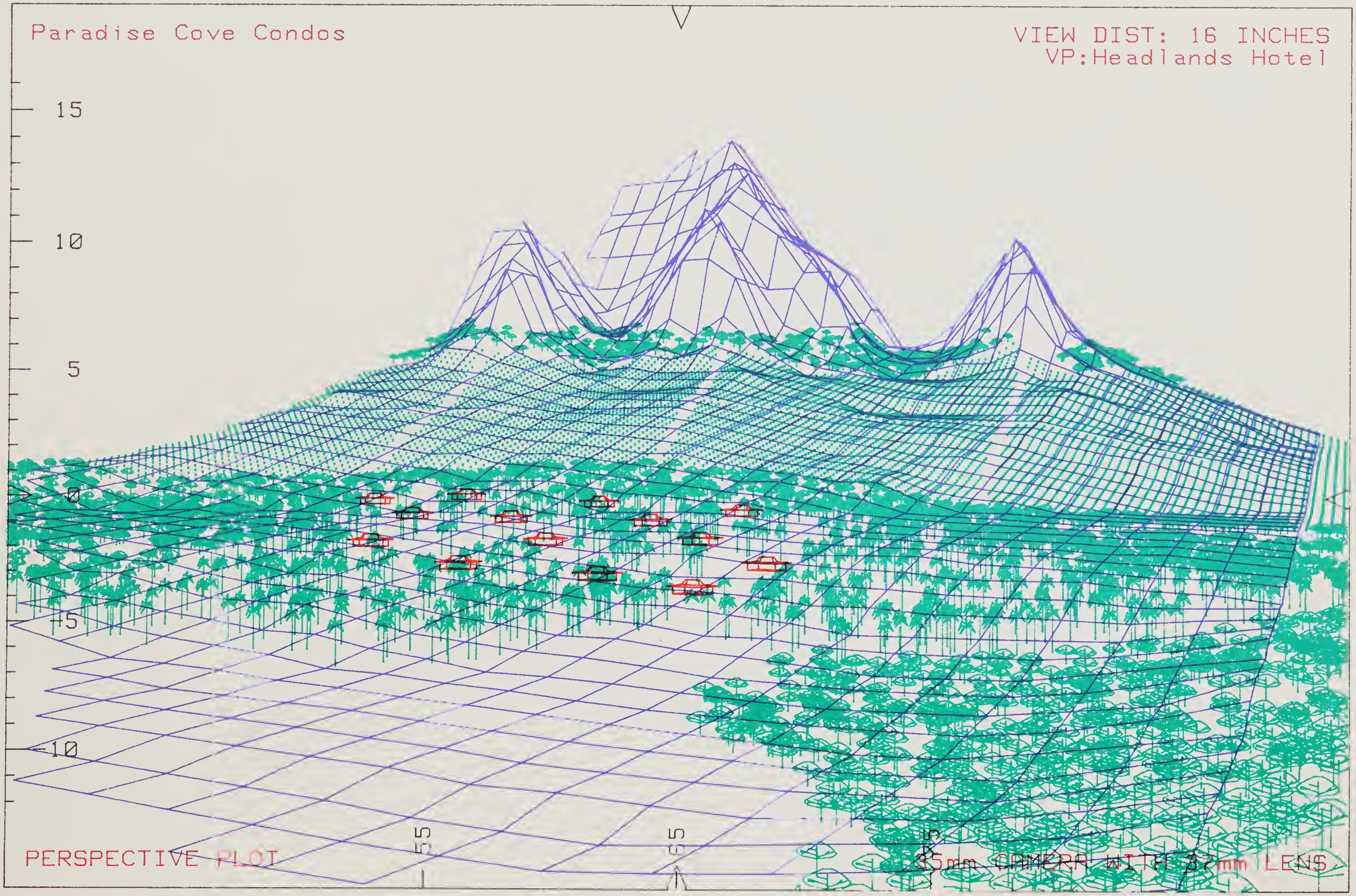


Figure C9-1. This perspective simulation shows the mixture of tropical hardwoods, coconut palms, pineapple plantation, and landforms visible from the Headland House Hotel in Paradise Cove, Hawaii. The condominium structures -- seen in red -- are centered in the landward vista, but fairly well screened by undisturbed foliage, and not of disproportionately large scale.

CASE STUDY 9: Proposed Condominiums
Paradise Cove, Kahoolawe, Hawaii

Sunshine Holidays, Inc. owns the luxurious Headlands House, an eighteen-floor resort hotel on the south side of Paradise Cove. The landward vista is typical of many Hawaiian landforms, moving from beaches intersected by lava headlands, to moderate midslopes, up to extremely steep, eroded, interior volcanic mountains. East of the hotel lies a small but challenging private golf course, bordering the beautiful sandy beaches of Paradise Cove. Inland from this, the native tropical vegetation -- consisting of Koa acacia and associated hardwood species -- is broken by a seventy-five-acre coconut palm plantation nearly one hundred years old. Upper slopes beyond this consist of deep, rich red volcanic soils, eroded from the volcanic inlands. These upper slopes are planted to pineapple fields, separated into 25- to 30-acre tracts by service roads. A narrow fringe of residual Koa jungle separates the upper end of pineapple cultivation from the emergent rocky, unvegetated cliffs.

The directors of Sunshine Holidays, Inc. have purchased a tract of land within the coconut palm plantation, and are considering construction of a 112-unit condominium complex. The favored plan consists of fourteen two-story, eight-unit, detached structures arranged in an open grouping. All units will be similar in outward appearance, with a long, low polynesian-style roofline.

Of particular concern to the directors is the appearance of the condominium structures imposed on an as-yet unbroken tropical landscape, as seen in landward view from the Headlands House Hotel. Three PERSPECTIVE PLOT outputs were obtained, plotted on clear acetate, to be combined as sequential projector overlays. These are:

1. Distorted-square topographic landform base
2. Vegetation cover types: plantation, coconut palms, Koa jungle
3. Condominium structures

Figure C9-1 shows these color graphics in combination. Alternate structure shapes and arrangements could be easily obtained as additional overlays to the same base. For example, Phase Two of the condominium project might be an additional twelve structures, raising the density considerably and requiring removal of many coconut palms. Or, Alternative B might involve five-story condo structures, instead of the units pictured in the telephoto shot, figure C9-2. As an aid in the firm's marketing effort, the seaward vista enjoyed by individual units might be valuable graphics, particularly considering the imposition of the eighteen-story Headlands House Hotel on this line-of-sight. The terrain and vegetation data has been captured on the data disks, and can be reused in many ways.

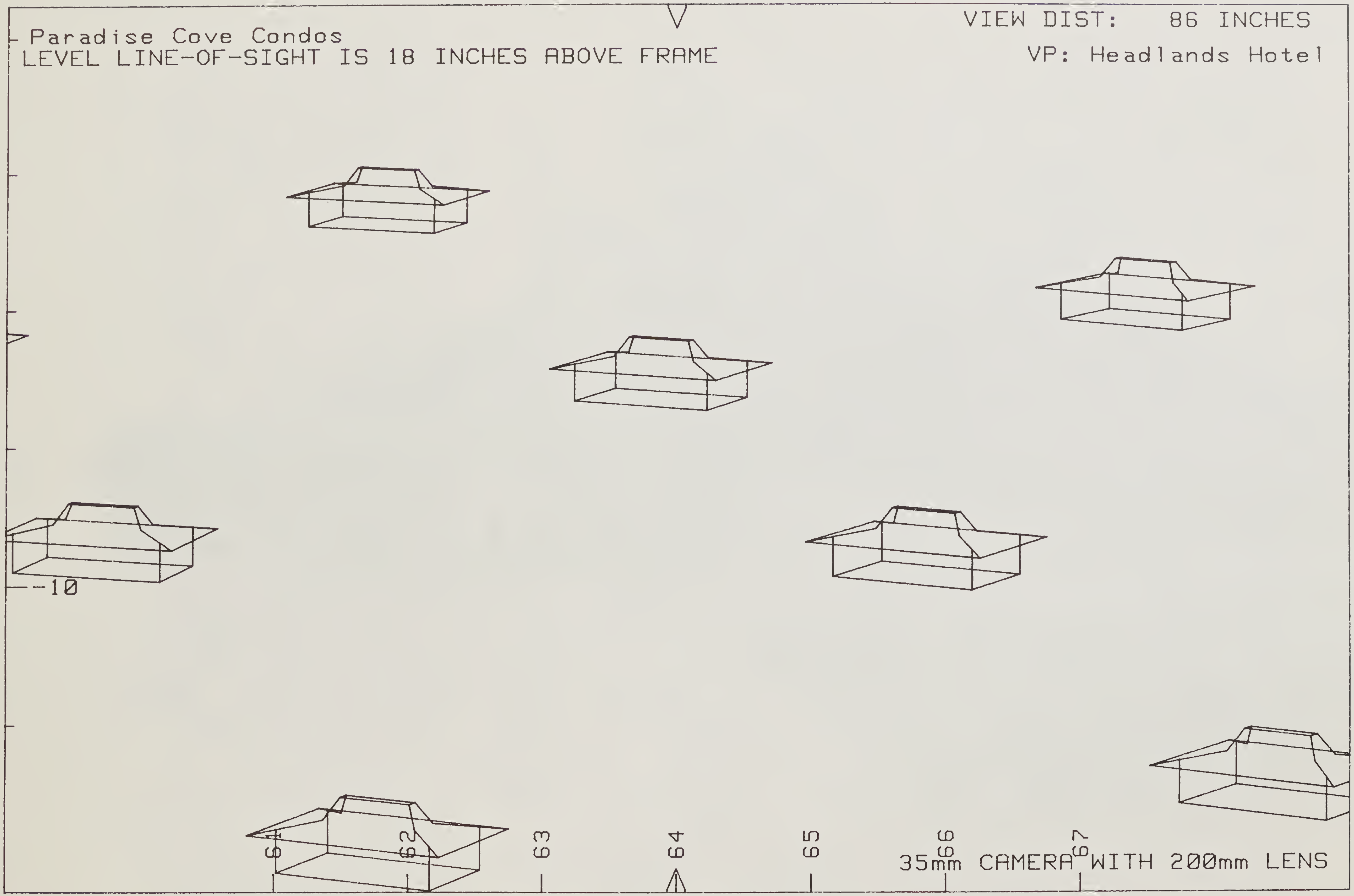


Figure C9-2. A close-up view of the condominium units.

Steps in obtaining CASE STUDY 9 graphics

	section
Startup	B1
Feature from Digital Terrain Model	B5
Constructing a Digital Terrain Model	B17
Storing a Digital Terrain Model	B18
Choose Digital Terrain Model Output	B20
Distorted-Square Terrain Depiction	B9
Viewpoint Location (Digitizer)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 1 -- Distorted-square Terrain Base	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Partialcut Timber Stand Boundaries	B10
Partialcut Timber Stand Depiction(modified)	B11
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 2 -- Vegetation Cover Types	
Choose Program Branching Option	B14
Choose Digital Terrain Model Output	B20
Feature from Digital Terrain Model(modified)	B5
Viewpoint Location (Coordinates)	B7
View Direction, Width-of-field	B8
Flat-bed Plotter Outputs	B15
Output No. 3 -- Condominium Structures	

APPENDIX I Recovery from Errors

The HP9845 operating system has an "editor" on duty at all times when programs are running. The editor will catch a large number of error situations and halt execution of a running program. The user is given an "error message" that may enable him to correct matters and restart the program. An awareness of common errors will help prevent their occurrence.

The "error message" is in one of two forms:

ERROR nn
or
ERROR nn IN LINE xxx

where nn is an error type code and xxx is a program line number. The error message appears on the lowest line of the CRT and is accompanied by a tone from the computer.

A pull-out error message card, located below the CRT, gives the meaning of each error type code. With reference to the program PERSPECTIVE PLOT, several of these errors are discussed more fully:

ERROR 11 Numeric value required

Some questions asked during the program PERSPECTIVE PLOT can be answered with an alphabetic response, like YES or NO, while others require numeric values. Note that there is a difference between the number Ø (zero) and the letter O. Using the letter O when a numeric value is required may be the most common source of ERROR 11.

To recover, type in the correct numeric value and press [CONT].

ERROR 17 Subscript out of range

Many values used in the program PERSPECTIVE PLOT are placed into a variable array. An example is the coordinate array -- a list of 500 coordinates, numbered (subscripted) 0 to 500, that describe the boundary of a discrete-point feature. When an attempt is made to define the 501st point, ERROR 17 occurs.

To recover, type in a permissible value and press [CONT].

ERROR 18 Substring out of range or string too long

Alphabetic responses, such a profile names, are strings of characters. A certain number of characters are reserved for each string. In the case of viewpoint names, the user is allowed up to eighteen characters. Exceeding the permissible size generates ERROR 18.

To recover, shorten up the string to an acceptable size and press [CONT]. NOTE: changing the last character(s) to blanks will not work, because blanks are recognized as characters! Use [DEL CHR] or [CLR- END] editing features to delete characters.

ERROR 56 File name is undefined

In the program PERSPECTIVE PLOT, this error may be encountered if:

1) the user has the wrong disc or tape when he attempts to load the program to begin with.
2) the user misspells the program name in the $\boxed{\text{LOAD}}$ statement.
3) the user requests a nonexistent profile storage file, or misspells the 2- or 3-letter profile storage file code, when storing skyline profiles (see section B21).

To recover, check to see that the proper disc or tape is used, type in the correct $\boxed{\text{LOAD}}$ statement or profile storage file code, then press $\boxed{\text{CONT}}$.

ERROR 80 Cartridge out or door open

The disc must be properly installed in the disc drive with the door closed, or ERROR 80 will occur.

To recover, check the disc and start at the beginning of program execution.

Improper Value Inputs

If an incorrect value is typed in, the entry can be changed with the edit keys (see APPENDIX II) prior to pressing $\boxed{\text{CONT}}$. Upon pressing $\boxed{\text{CONT}}$ the value is entered into the computer. To change the value, the user must step back in the program execution to a point prior to the error entry. Ample opportunity is provided for accomplishing this. See the discussion on Choose Program Branching Options.

Hopeless Foulup

When everything seems to go wrong and the user is hopelessly confused, it is time to:

STOP
REVIEW THE INSTRUCTIONS
START OVER AT THE BEGINNING

When None of the Above Suggestions Seems to Work

The program PERSPECTIVE PLOT was developed and is supported by the U.S. Forest Service Pacific Northwest Region's Logging Systems Group. If local computer support cannot handle a procedural or technical question, telephone the Logging Systems Group in Portland, Oregon:

Commercial: 503-221-3879
FTS: 423-3879

ON/OFF SWITCH

On/Off switch is a rocker-type switch located on the right-hand side of the base unit. When turned on, the HP9845 performs a series of internal status checks, taking about 15 seconds. Then the system is ready for use.

TYPEWRITER KEYBOARD

The typewriter keyboard is almost identical to a standard electric typewriter. The keyboard operates in 'teletype' mode -- letters are capitals unless the shift is held down. The TYPWTR key (in the upper-left "TYPING FUNCTIONS" block) changes this to 'typewriter' mode -- letters are lower-case unless the shift is held down.

NUMBERS

Either the number keys at the top of the typewriter keyboard, or the number key block (right side) may be used interchangeably. There is absolutely no difference in the characters produced.

AUTO START

The lower right key in the "EDIT FUNCTIONS" block (upper center) is the AUTO ST (automatic start) key. Press the key down and it stays down ("latched"). If the computer is turned on with this key latched, it automatically looks for, loads, and begins executing a program called "AUTOST" stored on a tape in the left-hand (T15) tape drive. If no tape is installed in the left-hand drive, or if there is no program AUTOST on the tape in the left-hand drive, an error (ERROR 80 or ERROR 56) occurs. The program PERSPECTIVE PLOT is not equipped with an automatic start sequence!

EXECUTE

The EXECUTE key is used to execute "system" commands. The only time this will be necessary in operating the PERSPECTIVE PLOT program is to EXECUTE the initial LOAD statement when running with disc.

RUN

The RUN key causes the computer to begin operating a program, once the program is loaded into the machine's memory.

STOP

The STOP key interrupts, and terminates, execution of a running program. The program may be re-started only at the beginning, by pressing RUN.

PAUSE

The PAUSE key interrupts execution of a running program. The program may be re-started exactly where it left off by pressing CONT. The program may be advanced one step at a time by pressing STEP.

CONTINUE

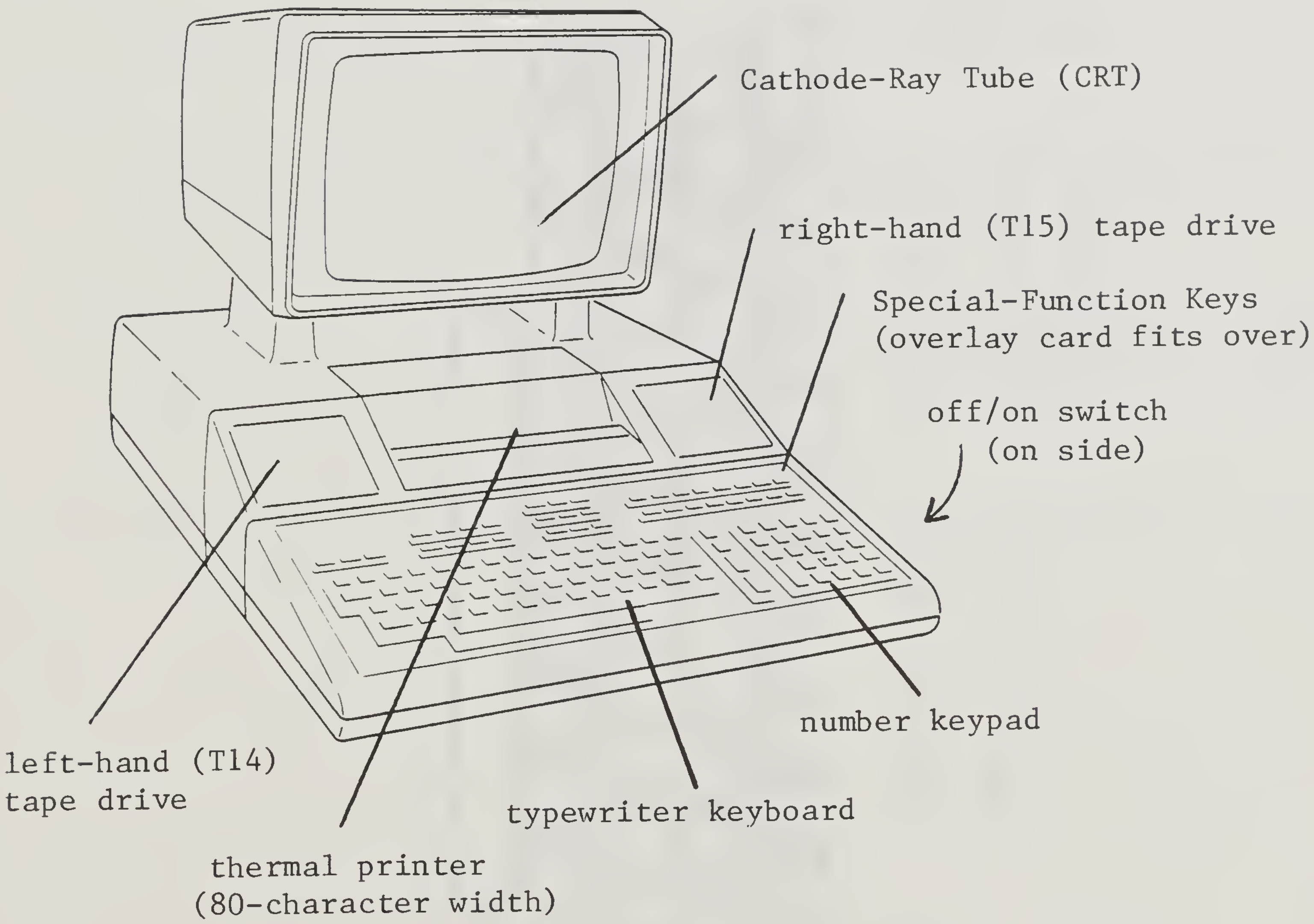
The CONT key is used to give input values to the computer, and allow the interrupted program to continue. When the computer prompts the user to type in a value, the value may be edited, erased, changed, and is not input into memory until CONT is pressed.

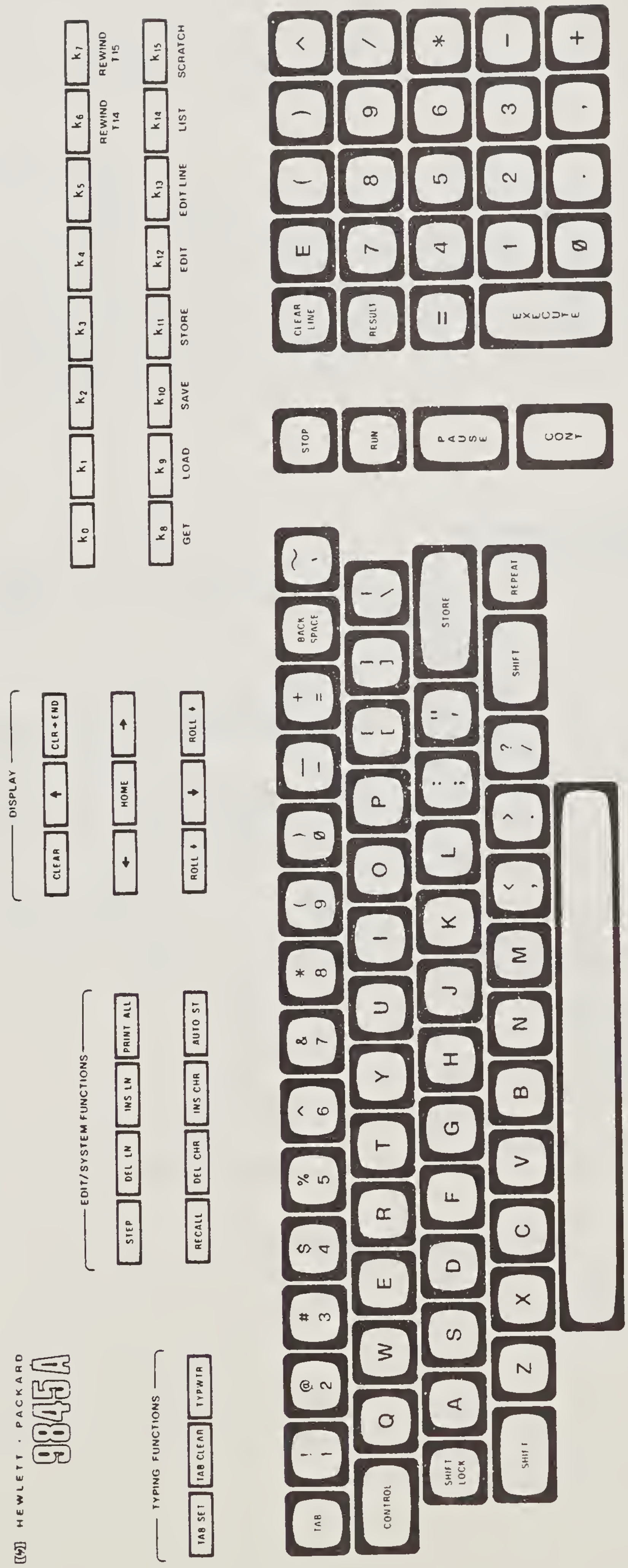
SPECIAL-FUNCTION KEYS

There are 16 special-function keys, labelled kØ -- k15, located in the upper right position. These keys interrupt the program and cause it to begin operation in a different spot. There are an additional 16 special functions obtained by holding the shift key down, but only the first (unshifted) 16 are used in the program PERSPECTIVE PLOT. The special-function keys are identified by a plastic overlay card, which fits down over the block of keys.

EDITING

Inputs may be edited prior to pressing CONT. CLEAR LINE erases the input entirely, allowing the user to start over. The -- key sends a flashing underscore back along the line of input characters, to any point where an error must be corrected. Just type the correct characters, and the erroneous ones vanish. The INS CHR key enables the insertion of characters, to the left of the flashing underscore. The DEL CHR key deletes the character over the flashing underscore. The CLR-> END key deletes everything to the right of the flashing underscore. Pressing the RECALL key brings back the last item input. In fact, a RECALL buffer holds a number of "last items" in a last-in-first-out arrangement. Continue to press RECALL and the sequence of items back into the RECALL buffer will be displayed. Holding the shift key and pressing RECALL enables movement forward through the recall buffer.


Cathode-Ray Tube (CRT)
right-hand (T15) tape drive
Special-Function Keys
(overlay card fits over)
off/on switch
(on side)
number keypad
left-hand (T14)
tape drive
typewriter keyboard
thermal printer
(80-character width)


HEWLETT · PACKARD
9845A
TYPING FUNCTIONS
TAB SET
TAB CLEAR
TYPWTR
EDIT/SYSTEM FUNCTIONS
STEP
DEL LN
INS LN
PRINT ALL
RECALL
DEL CHR
INS CHR
AUTO ST
DISPLAY
CLEAR
CLR→END
HOME
ROLL ↑
ROLL ↓
k0 k1 k2 k3 k4 k5 k6 k7
REWIND T14
REWIND T15
k8 k9 k10 k11 k12 k13 k14 k15
GET LOAD SAVE STORE EDIT EDIT LINE LIST SCRATCH
TAB
CONTROL
SHIFT LOCK
SHIFT
BACK SPACE
STORE
REPEAT
STOP
RUN
PAUSE
CONT
CLEAR LINE
RESULT
EXECUTE

RELATED PUBLICATIONS

__________. "Our National Landscape -- a Conference on Applied Techniques for Analysis and Management of the Visual Resource". Symposium proceedings, USDA Forest Service PSWF&RES, April 1979.

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Travis, M., G. Elsner and P. Kourtz. "A Computer Software Package to Convert Digitized Geographic Boundary and Contour Data to a Uniform Grid Structure" Forest Fire Res. Inst. Report FF-X-44, 1973.

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